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APPENDIX A. BIOLOGICAL INFORMATION FOR HCP SPECIES

The species addressed in this plan include the listed (state and federal endangered and threatened) and sensitive species that may be affected by the maintenance and repair, operation, habitat enhancement and monitoring activities identified in the plan. Table A-1 lists the species and their status.

Table A-1. List of Sensitive Species within the Contra Costa and Pittsburg Power Plants Habitat Conservation Plan Area

Common Name	Scientific Name	State Status[1]	Federal Status[1]
Delta smelt[2]	*Hypomesus transpacificus*	T	T
Longfin smelt	*Spirinchus thaleichthys*	None	None
Winter-run chinook salmon[2]	*Oncorhynchus tshawytscha*	E	E
Spring-run chinook salmon	*Oncorhynchus tshawytscha*	None	None
Fall/late fall-run chinook salmon	*Oncorhynchus tshawytscha*	None	PT
Steelhead	*Oncorhynchus mykiss*	None	T
Sacramento splittail	*Pogonichthys macrolepidotus*	None	PT
Green sturgeon	*Acipenser medirostris*	None	None
Soft bird's-beak	*Cordylanthus mollis* ssp. *mollis*	Rare	PE
California black rail	*Laterallus jamaicensis coturniculus*	T	None
California clapper rail	*Rallus longirostris obsoletus*	E	E
California least tern	*Sterna antillarum browni*	E	E
Salt marsh harvest mouse	*Reithrodontomys raviventris*	E	E

[1] **STATUS:**
E = Endangered; **T** = Threatened; **PT** = Proposed Threatened; **PE** = Proposed Endangered; **C** = Candidate.

[2] Critical habitat has been designated for Delta smelt in the Pittsburg and Contra Costa Power Plants and the Montezuma Enhancement site HCP areas. Critical habitat has been designated for winter-run salmon in the Pittsburg Power Plant and Montezuma Enhancement site HCP areas. Critical habitat has not been designated at this time for any of the other species listed in this document.

Existing biological information about species distribution, occurrence, and ecology is presented below for all of the addressed sensitive species. Most of the information for the fish species was taken from the **Sacramento-San Joaquin Delta Native Fishes Recovery Plan** (USFWS 1996). The information for the winter-run chinook salmon profile was taken from the **Working Paper on Restoration Needs for Central Valley Anadromous Fish** (USFWS 1995) and the **Action Plan for Restoring Central Valley Streams** (CDFG 1993). For steelhead, the **Steelhead Restoration and Management Plan for California** (CDFG 1996) was the primary source of information for this species. The information for the rest of the species was compiled from numerous existing sources.

Delta Smelt (*Hypomesus transpacificus*)

Status: Delta smelt are listed as threatened by the USFWS and CDFG. The species is endemic to the Sacramento-San Joaquin estuary. Critical habitat has been designated for this species.

Life History: Delta smelt are a schooling species that prefer low-salinity water and are most abundant in the upper portion of the water column. Delta smelt are most often found in open, surface waters of the Delta and Suisun Bay. The adults migrate from slightly brackish water into freshwater areas in the winter and spring for spawning.

Spawning has been documented between January and July (Wang 1986, Sweetnam and Stevens 1993). The timing of the spawning season can vary with the amount of freshwater outflow in the late winter/early spring and associated water temperatures. Wang (1986) reports spawning taking place in freshwater at temperatures of about 7-15°C. However, ripe Delta smelt and larvae have been collected in recent years at temperatures of 15-22°C, so it is likely that spawning can occur over the entire 7-22°C range. Temperatures that are optimal for survival of embryos and larvae have not yet been determined, although R. Mager (University of California, Davis [UCD] unpublished data) found low hatching success and embryo survival from spawns of captive fish collected at higher temperatures. In low outflow years, spawning occurs from late March through mid-May. Most spawning occurs in sloughs and shallow edge-waters of channels in the upper Delta and in the Sacramento River above Rio Vista, although it has been recorded in Montezuma Slough near Suisun Bay (Wang 1986) and also may occur in Suisun Slough in Suisun Marsh (P. Moyle, UCD, unpublished data). Delta smelt eggs are demersal and adhesive, sticking to hard substrates (Moyle 1976, Wang 1986). At 14-16°C, embryonic development to hatching takes 9-14 days (R. Mager, UCD, unpublished data).

Newly hatched Delta smelt have a large oil globule that makes them semi-buoyant, allowing them to maintain themselves just off the bottom (R. Mager, UCD, unpublished data), where they feed on rotifers and other microscopic prey. As the swim bladder develops, larvae become more buoyant and rise higher into the water column. At this stage (16–18 mm in total length), most of the young fish move downstream to the mixing zone (null zone). Growth is rapid and juvenile fish are 40–50 mm in length by early August (Erkkila et al. 1950, Ganssle 1966, Radtke 1966). By this time, young-of-the-year fish dominate trawl catches of delta smelt, and adults become rare. Delta smelt reach 55–70 mm SL in 7–9 months (Moyle 1976). Growth during the next 3 months slows considerably (only 3–9 mm total), presumably because most of the energy is being directed toward gonadal development (Erkkila et al. 1950, Radtke 1966). Females between 59 and 70 mm SL lay 1,200-2,600 eggs (Moyle et al. 1992). The abrupt change from a single-age, adult cohort during spawning in spring to a population dominated by juveniles in summer suggests that most adults die after they spawn (Radtke 1966).

Delta smelt feed primarily on planktonic copepods, cladocerans, amphipods, and insect larvae. Larger fish may also feed on the opossum shrimp (*Neomysis mercedis*). The most important food organism for all sizes seems to be the euryhaline copepod (*Eurytemora affinis*), although in recent years the exotic species, *Pseudodiaptomus forbesi,* has become a major part of the diet (Moyle et al. 1992).

Abundance: Delta smelt were once one of the most common pelagic fish in the upper Sacramento–San Joaquin estuary (Erkkila et al. 1950, Radtke 1966, Stevens and Miller 1983). Delta smelt abundance has fluctuated greatly in the past, but from 1982 to 1992 their population remained consistently low. The decline became precipitous in 1982 and 1983 due to extremely high outflows and continued through the drought years 1987–1992 (Moyle et al. 1992). In 1993, numbers increased considerably, apparently in response to a wet winter and spring. In 1982–1992, most of the population was confined to the Sacramento River channel between Collinsville and Rio Vista (D. Sweetnam, CDFG, unpublished data). This was still an area of high abundance in 1993, but Delta smelt were also abundant in Suisun Bay. The current size of the Delta smelt population is not known. Population estimates were generated for 8 years during the 1968-1985 period by Stevens et al. (1990). The estimates ranged from a high of 2.67 million in 1971 to a low of about 230,000 in 1977. The most recent estimate was calculated in 1985 at about 280,000 fish. These population estimates were generated by multiplying the ratio of Delta smelt and young striped bass collected in CDFG's fall midwater trawl survey by a rough estimate of the striped bass population which was available for the 8 years. This technique was based on a statistical analysis which made assumptions that have been criticized and described as misleading (Herbold 1996), suggesting that the estimates may not be accurate.

Distribution: Delta smelt occur in the Delta primarily below Isleton on the Sacramento River, below Mossdale on the San Joaquin River, and in Suisun Bay. During their spawning migrations upriver, Delta smelt can occur in the Sacramento River as far upstream as Sacramento, the Mokelumne River system, the Cache Slough region, the Delta, and Montezuma Slough. During high outflow periods, they may be washed into San Pablo Bay, but they do not establish permanent populations there. Between 1982 and 1992, the center of Delta smelt abundance was the northwestern Delta in the Sacramento River channel. However, high outflows in winter of 1992/1993 allowed Delta smelt to recolonize Suisun Bay in 1993 (D. Sweetnam, CDFG, unpublished data). Delta smelt are captured seasonally in Suisun Marsh.

Habitat Requirements: Delta smelt are euryhaline fish that rarely occur in water with salinities more than 10-12 ppt. Historically, they have been most abundant in shallow areas where early spring salinities are around 2 ppt. During the drought of 1987/1992, Delta smelt were concentrated in deep water areas in the lower Sacramento River near Emmaton, where average salinity ranged from 0.36 to 3.6 ppt for much of the year (California Department of Water

Resources and U.S. Bureau of Reclamation 1994). During years with wet springs (such as 1993), Delta smelt may continue to be abundant in Suisun Bay during summer even after the 2 ppt isohaline has retreated upstream (Sweetnam and Stevens 1993). Fall abundance of Delta smelt is generally highest in years when salinities of 2-ppt are in the shallows of Suisun Bay during the preceding spring (Herbold 1994).

Delta smelt of all sizes are found in the main channels of the Delta and Suisun Marsh and the open waters of Suisun Bay where the waters are well oxygenated and temperatures relatively cool (usually less than 20–22°C in summer). Delta smelt tend to be concentrated near the zone where incoming salt water and outflowing fresh water mix (mixing zone). This mixing area has the highest primary productivity and zooplankton populations in the estuary (Knutson and Orsi 1983, Orsi and Mecum 1986).

Occurrence at the Pittsburg and Contra Costa Power Plants: Delta smelt may occur in the vicinity of the Contra Costa and Pittsburg Power Plants at any time of the year, depending on the salinity of the water near the plants. Under conditions of high outflow, most of the fish will be concentrated in Suisun Bay, west of the Pittsburg facility. This was the case in 1995 (through July) as reflected in the PG&E Delta smelt monitoring program. This program was conducted from June through August. During this period, 316 Delta smelt were collected: 312 from two sites near the Pittsburg Power Plant, 2 from the San Joaquin River site, and 2 from the offshores site at Contra Costa Power Plant. In August, the salinity values increased at Pittsburg to around 1 ppt and the densities of Delta smelt increased at Pittsburg Power Plant. The Contra Costa Power Plant is located upriver from Pittsburg, and the salinities remained low through August. These results suggest that during relatively high Delta inflows, Delta smelt can occur near the Pittsburg Power Plant in relatively high abundance and, at the same time, be at a very low abundance near Contra Costa Power Plant. Under conditions of low flow (1987-1992), the Delta smelt population was concentrated to the east of the power plants on the Sacramento River. The salinity regime in the vicinity of the power plants will determine the distribution of Delta smelt near the facilities. Facilities are located in areas where critical habitat has been designated.

Longfin Smelt (*Spirinchus thaleichthys*)

Status: Longfin smelt have no official state or Federal status.

Life History: Longfin smelt generally are euryhaline and anadromous. In the Sacramento–San Joaquin estuary, longfin smelt are concentrated in central San Francisco Bay, although some have been caught offshore (USFWS 1996). Adults and juveniles can be found in water ranging from pure seawater to completely freshwater during upriver spawning migrations. The preference of larval longfin smelt for the upper part of the water column allows them to be swept quickly into food-rich nursery areas downstream, mainly Suisun and San Pablo bays. During years when periods of high outflows coincide with the presence of the larval longfin smelt (e.g., 1980, 1982, 1983, 1984, and 1986), the larvae are transported to Suisun and San Pablo bays; in years of lower outflow, the larvae end up in the less-productive western Delta.

During the fall, the distribution of yearling longfin smelt gradually shifts upstream, a change that coincides with development of the gonads in preparation for spawning. They congregate for spawning at the upper end of Suisun Bay, in the lower and middle Delta, in the Sacramento River channel, and in adjacent sloughs. This distribution pattern may represent a change from the historic pattern. The CDFG fall midwater trawl data indicate that longfin smelt were scarce in the Sacramento River and the Delta prior to 1977 (a second year of drought); after 1977, they became more common in the upstream catches.

Larval longfin smelt are generally collected below Medford Island in the San Joaquin River and below Rio Vista on the Sacramento River (Wang 1991), indicating that spawning rarely occurs above these locations. The lower end of the major spawning area seems to be upper Suisun Bay around Pittsburg, Montezuma Slough, and Suisun Marsh (Wang 1986). Adult movements and the presence of larvae in some December plankton samples indicate that some spawning may occur as early as November (R. Baxter, unpublished data) while larval surveys indicate spawning may occur into June (Wang 1986, 1991). Most spawning occurs from February through April, and has been documented at water temperatures of 7.0–14.5°C (Wang 1986). The eggs are adhesive (Dryfoos 1965) and are deposited either on rocks or aquatic plants. Each female lays 5,000–24,000 eggs (Dryfoos 1965, Moyle 1976.). The eggs hatch in 40 days at 7°C (Dryfoos 1965). Most longfin smelt die after spawning. A few individuals, mainly 1-year-old females, live another year and probably spawn a second time (USFWS 1996).

Newly hatched longfin smelt larvae are 5–8 mm long (Wang 1991). Metamorphosis into the juvenile form probably begins 30–60 days after hatching, depending on temperature (Emmett et al. 1991). Larvae and early juveniles tend to concentrate in the upper part of the water column, but at around 20 mm they may drop down into deeper water (USFWS 1996). Most growth occurs in the first 9-10 months of life, when the fish typically reach 60–70 mm SL. Growth rate levels off during the first winter, but there is another period of growth during the second summer and fall, when the fish reach 90–110 mm SL. The largest longfin smelt are 120–140 mm SL, presumably females in their third year of life.

The main food of longfin smelt is the opossum shrimp (*Neomysis mercedis*), although copepods and other crustaceans are important at times (Dryfoos 1965, Moyle 1976). Longfin smelt, in turn, are eaten by a variety of predatory fishes, birds, and marine mammals.

Abundance: Longfin smelt populations declined by 90% between 1984 and 1992 in the Sacramento–San Joaquin estuary (Meng 1993) and apparently have disappeared in recent years from the Eel River estuary and from Humboldt Bay on the north coast.

Historically, in the Sacramento–San Joaquin estuary, longfin smelt were one of the most abundant fish. The CDFG fall midwater trawl survey of the upper estuary, the CDFG otter and midwater trawl surveys, and the UCD Suisun Marsh surveys consistently caught longfin smelt in large numbers until the early 1980s (Herbold et al. 1992). The numbers of longfin smelt fluctuated widely, reaching their lowest levels during drought years but quickly recovering when adequate winter and spring flows were once again present. Since 1982, longfin smelt numbers have plummeted and have remained at record low numbers (Herbold et al. 1992). In fact, the catch of longfin smelt in the fall midwater trawl surveys since 1984 has consistently been lower than would be predicted by the regression equation of catch versus outflow in 1967–1984. For example, in 1982, the fall midwater trawl abundance index for longfin smelt was 62,929, the second highest on record; in 1992, the index was 73, the lowest on record. The fall index in 1993 (792) increased in response to the increased outflows but was still below the numbers that would be predicted based on the past outflow-abundance relationship (USFWS 1996). The longfin smelt has declined in abundance relative to other fishes, dropping from being first or second in abundance in most trawl surveys during the 1960s and 1970s to being seventh or eighth in abundance (Herbold et al. 1992).

Distribution: Populations of longfin smelt in California have been present in the Sacramento–San Joaquin estuary, Humboldt Bay, the Eel River estuary, and the Klamath River estuary. In the Sacramento–San Joaquin estuary, longfin smelt are rarely found upstream of Rio Vista or Medford Island in the Delta. Adults occur seasonally as far downstream as South Bay, but they are concentrated in Suisun, San Pablo, and North San Francisco bays. They are rarely collected outside the estuary. The southernmost record of the species' range is a single fish from Monterey Bay (Eschmeyer et al. 1983, Wang 1986), probably flushed out of the Sacramento–San Joaquin estuary.

Outside of California, longfin smelt are reportedly found in estuaries from Oregon to Prince William Sound, Alaska. Emmett et al. (1991) infers that longfin smelt are common in Skagit Bay, Grays Harbor, and Willapa Bay in Washington, highly abundant in the Columbia River, and common in Yaquina and Coos bays, Oregon. However, most of the Oregon and Washington inferences are not based on actual sampling and may contradict the results of field programs. For example, longfin smelt have rarely been collected in Coos Bay in the past 20 years despite intensive fish sampling programs (USFWS 1996). Landlocked populations occur in Lake Washington, Washington, and Harrison Lake, British Columbia (Dryfoos 1965).

Habitat Requirements: Adult and juvenile longfin smelt occupy the middle or bottom of the water column in the salt or brackish water portions of the estuary, although larval longfin smelt are concentrated in near-surface brackish waters (USFWS 1996). There is a strong positive correlation between winter-spring Delta outflow and longfin smelt abundance in fall of the same year. Higher flows increase the rate of transport and dispersal of larvae and juveniles into rearing habitat in Suisun and San Pablo bays. High flows also reduce the amount of time the larvae are retained in the Delta, where they are exposed to entrainment and higher concentrations of pesticides.

High freshwater outflows also increase the volume of brackish water (2–18 ppt salinity) rearing habitat required by larval and juvenile longfin smelt (R. Baxter, CDFG, unpublished data). Because the life history of longfin smelt is similar to that of striped bass, it is likely that longfin smelt larvae, like striped bass larvae, have higher survival rates in brackish water (Hall 1991). In most years, adults are found primarily in Suisun, San Pablo, and San Francisco bays. However, in low outflow years, they can concentrate in eastern Suisun Bay and the Delta. Average summertime salinities in Suisun Bay normally were <8 ppt even in dry years prior to the recent longfin smelt decline.

Occurrence at the Pittsburg and Contra Costa Power Plants: The highest concentrations of longfin smelt have historically been located west of the Pittsburg Power Plant. However, during upriver spawning migrations or when the salinity increases to a moderate level near the power plants, longfin juveniles and adults will move into the area and be exposed to impingement. Larval longfin smelt may be exposed to entrainment at the facilities as they move downriver to Suisun and San Pablo bays, depending on where spawning occurs. As described above, the spawning location can move to different areas within the estuary each year, depending on the amount of freshwater outflow in the late winter and spring.

Sacramento Winter-run ESU Chinook Salmon (*Oncorhynchus tshawytscha*)

Status: Sacramento winter-run ESU chinook salmon were designated as endangered by NMFS in 1992 and by the CDFG in 1989. Critical habitat has been designated for this species.

Life History: Most winter-run chinook salmon migrate into the Sacramento River at age 3. Currently, all winter-run fish spawn in the main stem of the river. The adults move under the Golden Gate from November through May and spawn in the main stem from mid-April through August. Adult winter-run fish can spend a relatively long time in the river prior to spawning. Incubation occurs from mid-April through October. Healy and Heard (1984) found that the fecundity of chinook salmon ranged from fewer than 2,000 to more than 17,000 eggs. Incubation time is inversely related to water temperature. Hatching occurs in 6-9 weeks. The fry emerge from July through May and rear in freshwater prior to smolting. The smolts move downriver from January through May. Most winter-run smolts migrate through the Delta from January through March (USFWS 1995).

Abundance and Distribution: Winter-run chinook salmon historically used the upper reaches of the McCloud, Pit, and Little Sacramento rivers, and Battle Creek. Starting in the 1940s, access to these upper reaches was blocked by the completion of Shasta and Keswick dams. The winter-run fish continued to use the main stem, taking advantage of the cool water below the newly constructed dams. The runs averaged 80,000 adults in the late 1960s, reaching a high of 117,808 spawners in 1969. However, beginning in 1970, winter-run numbers dropped greatly. A few winter-run were observed in the Calaveras River during the 1980s (CDFG 1993). The winter-run population is currently limited to the main stem of the Sacramento River below Keswick Dam. The lowest total to date was 191 adults in 1991. In 1992 and 1993, the numbers of adults were 1,180 and 341, respectively.

Factors contributing to the decline include high water temperatures, passage problems at the Red Bluff Diversion Dam, modifications of spawning and rearing habitat, predation, pollution, and entrainment. The recent drought in California (1987-1992) may have exacerbated these impacts.

Occurrence at the Pittsburg and Contra Costa Power Plants: Winter-run adults move upstream through the Delta and into the Sacramento River from December through July. The adults do not spawn immediately and sometimes remain in the river for up to several months before spawning. During incubation and fry rearing periods, cool water temperatures in the main stem are desirable for optimal survival. Facilities are located in areas where critical habitat has been designated.

Adult winter-run salmon move past Contra Costa and Pittsburg power plants very quickly during their upriver migrations, spending little time within the lower sections of the Sacramento and San Joaquin rivers. Delays in adult migration do not occur because large adult fish can easily avoid any potential barrier due to the power plants. The smolts may be exposed to the intakes during their downriver migration, but by the time these fish reach the western edge of the Delta, they are large enough to avoid effects from the power plants and, in general, head to the ocean as quickly as possible, minimizing the period of potential exposure. Facilities are located in areas where critical habitat has been designated.

Central Valley Spring-run ESU Chinook Salmon (*Oncorhynchus tshawytscha*)

Status: Central Valley spring-run ESU chinook salmon have no official state status, but are federally proposed as endangered.

Life History: In general, spring chinook salmon migrate considerable distances upstream to spawn. They enter the rivers from March through June. Historically, these migrating fish were a mixture of age classes ranging from 2 to 5 years old. At the present time, most of the fish are probably 3-year-olds. While migrating and holding in the river, spring chinook do not feed, relying instead on stored body fat reserves for maintenance and gonadal maturation. The runs also may be bimodal, with some fish holding downstream to migrate later in the summer, possibly because of increasing water temperatures later in the spring (Marcotte 1984). Using visual cues, they are fairly faithful to home streams in which they were spawned. However, some may become disoriented, especially during high-water years, and ascend streams where they were not spawned.

When they enter freshwater, spring chinook are immature; their gonads mature during the summer holding period (Marcotte 1984). Fish hold in deep pools in upstream reaches during the summer and spawn in early fall. Pre-spawning activity has been observed by mid-August, and intensive redd-building activity and spawning occurs from the last week of August through the end of October (Parker and Hanson 1944; F. Fisher, as cited in USFWS 1996). In Deer Creek, spawning is generally completed by late September (Moyle, unpublished observation). Spawning first occurs in the upper reaches of streams and subsequently in lower reaches, as water temperatures decrease (Parker and Hanson 1944). Spawning salmon usually are well distributed within a stream section, reducing competition for redd sites (Cramer and Hammack 1952). Eggs are laid in large depressions hollowed out in gravel beds (redds). The embryos hatch following a 3- to 5- month incubation period and the alevins (sac-fry) remain in the gravel for another 2-3 weeks. Once their yolk sac is absorbed, juveniles emerge and begin feeding. In Deer and Mill creeks, juvenile salmon spend 9-10 months in the streams during most years, although some may spend as long as 18 months in freshwater (USFWS 1996). By the end of summer, they are 8-10 cm SL (Moyle, unpublished observation). Their main food during this period is drifting aquatic insects. Most of the juveniles seem to move downstream in the first high flows of winter in November through January, although some may persist through March (USFWS 1996). In the Sacramento River, most downstream movement seems to occur in December-February as parr (Vogel and Marine 1991). Out-migrants may spend some time in the Sacramento River or estuary to gain additional size before smolting and going out to sea, but most have presumably left the system by mid-May. Once in the ocean, salmon are largely piscivorous and grow rapidly, reaching 80-100 cm SL in 2–3 years.

Abundance: Spring-run chinook salmon of the Sacramento-San Joaquin River system historically comprised one of the largest runs on the Pacific coast. Commercial gillnet fishery landings of spring chinook in the Central Valley exceeded 600,000 fish in 1883 (California Fish and Game Commission 1885). Runs in the San Joaquin River alone probably exceeded 200,000 fish at times, and it is likely that an equal number of fish were once produced by the combined spring runs in the Merced, Tuolumne, and Stanislaus rivers. However, early historical population levels were never measured (CDFG 1990). In 1955, the CDFG estimated that with proper water management the San Joaquin drainage could still produce about 210,000 wild chinook salmon per year, with fall-run chinook replacing the spring-run populations lost to dam construction (CDFG 1955). The last large run in the San Joaquin River occurred in 1945, when 56,000 fish made it up the river (Fry 1961). The San Joaquin River spring chinook run has since been extirpated primarily due to the dewatering of the lower San Joaquin River following construction of Friant Dam in 1948, as well as blockage by the dam to upstream areas (Warner 1991).

After the demise of the San Joaquin stocks, Sacramento River spring chinook salmon constituted the most abundant natural runs in the Central Valley. As in the San Joaquin drainage, these spring chinook populations were also drastically reduced following construction of barrier dams. Historic run sizes for tributaries to the Sacramento River were estimated by the CDFG (1990) to be 15,000+ above Shasta Dam (McCloud River, Pit River, Little Sacramento River), 8,000–20,000 in the Feather River above Oroville Dam, 6,000–10,000 in the Yuba River above Englebright Dam, and 10,000+ in the American River above Folsom Dam. The Sacramento River drainage as a whole is estimated to have supported spring chinook runs exceeding 100,000 fish in many years between the late 1800s and 1940s (Campbell and Moyle 1990).

The decline of spring chinook in the Sacramento drainage began when spawning streams were disrupted by gold mining and irrigation diversions. The decline accelerated following closure of Shasta Dam in 1945. This closure cut off access to major spawning grounds in the McCloud, Pit, and upper Sacramento rivers. In recent years, the decline has continued. Estimates by the CDFG of spawning escapement in the mainstem Sacramento River ranged from 3,600 to 25,000 fish between 1969 and 1980, with an average population of 17,000 fish per year (Marcotte 1984). However, most of these fish probably originated in the Feather River Hatchery and were therefore mixed fall- and spring-run stock. In Deer and Mill creeks, estimates of spawning fish averaged 2,300 and 1,200 fish, respectively (Marcotte 1984). Since 1985, combined yearly totals for both creeks have been less than 900 fish, with the exception of 1989 when there were about 1,300 fish. Spawning populations in other tributary streams are considerably less. Spring chinook numbers in Antelope Creek have dropped during the last few years to <10 individuals per year (USFWS 1996). Up to 100 fish have held in Big Chico Creek (Marcotte 1984), but the stream currently supports a much smaller run of probably less than 20 adults (USFWS 1996). In Butte Creek, numbers have fluctuated considerably from year to year and in the past have been augmented by fish from the Feather River Hatchery. However, about 1,300 adults held in the creek in both 1988 and 1989. These may have resulted from natural reproduction, but it is also possible that they were fish from the Feather River Hatchery attracted to the creek by Feather River water PG&E diverts into the creek to run its powerhouse. Recent counts in Butte Creek have dropped to 300+ fish in 1990, 100+ in 1991, and 300+ in 1992 (E. Gerstung, unpublished data).

Prior to dam construction, spatial segregation of runs by downstream and upstream spawning sites maintained their genetic integrity. When major dams began releasing cold water into lower reaches of the main rivers, spring chinook began to over-summer and spawn in what had been exclusive fall chinook spawning habitat. As a consequence, spring chinook in the Sacramento River have interbred with fall-run fish (Vogel 1987a,b).

Overall population trends for spring chinook salmon in California are described by Campbell and Moyle (1990). They report that more than 20 historically large populations of spring-run chinook have been extirpated or reduced nearly to zero since 1940. Four additional runs (Butte, Big Chico, Deer, and Mill creeks) have exhibited statistically significant declines during the same period. The only substantial, essentially wild populations of spring-run chinook remaining in California are in Deer and Mill creeks in the Sacramento drainage and in the Salmon River in the Klamath-Trinity drainage (Campbell and Moyle 1990). Other populations tend to be supported by hatchery stocks.

Distribution: Spring chinook salmon are found in rivers in British Columbia, Washington, Idaho, Oregon, and California, but their populations are depleted throughout this range or maintained by hatchery production (Shepherd 1989). Spring-run chinook also occur in substantial populations in Alaska (Healey 1991), but their genetic affinities with more southern populations are unclear. In California, spring chinook were once abundant in all major river systems. There were large populations in at least 26 streams in the Sacramento–San Joaquin drainage and at least 20 streams in the Klamath-Trinity drainage (CDFG 1990). Spring chinook are now reduced to scattered populations in the Klamath, Trinity, and Sacramento drainages (Campbell and Moyle 1991), with small numbers (probably strays) found in the Smith River, Redwood Creek, Mad River, Mattole River, and Eel River.

In the Sacramento–San Joaquin drainage, principal holding and spawning areas were in the middle and headwater reaches of the San Joaquin, Feather, upper Sacramento, McCloud, and Pit rivers, presumably with smaller populations in most of the other tributaries large and cold enough to support the salmon through the summer. The main populations were extirpated when dams were constructed, blocking access to the holding areas, primarily in the 1940s and 1950s (but starting in the 1890s). Today, the most consistent self-sustaining wild populations in the drainage are in Deer and Mill creeks, Tehama County, with a few fish present in Antelope, Battle, and Big Chico creeks in some years (Vogel 1987a,b; Sato and Moyle 1988). Substantial numbers of spring chinook can also be present in Butte Creek, but numbers have been highly variable (100–1,500 fish between 1982 and 1992). Juveniles from the CDFG Feather River Hatchery have been planted there in the past (including 1984 and 1985), and because PG&E diverts Feather River water into Butte Creek for power production, Feather River Hatchery fish may be attracted to it. Spawning habitat is largely lacking in the reaches above Centerville, but there are adequate spawning gravels and holding pools in the lower reaches. Natural reproduction in Butte Creek may nevertheless be disrupted by regulated flow regimes (the stream is regulated for hydroelectricity), high temperatures, poaching, and other human disturbance. Historically, Butte Creek apparently had very small runs of spring chinook (Clark 1929). However, in 1989, large numbers of spring chinook occupied Butte Creek, and these fish apparently were derived from natural spawning in the creek (USFWS 1996). In the Feather River, a run of fish labeled as spring-run is maintained by hatchery production. In 1986, for example, 1,433 adults were captured and over 1.6 million fingerlings were planted (Schlichting 1988).

Habitat Requirements: For spring chinook adults, numbers holding in an area seem to depend on the volume and depth of pools, amount of cover (especially bubble curtains created by inflowing water), and the proximity to patches of gravel suitable for spawning (G. Sato, BLM, unpublished data). Mean water temperatures in pools where adult chinook held during the summer of 1986 in Deer and Mill creeks were 16°C (range 11.7–18°C) and 20°C (range 18.3–21.1°C), respectively, and for juveniles in Mill Creek the temperature ranged from 13.3 to 22.2°C (Sato and Moyle 1988). Records indicate that spring chinook in the Sacramento–San Joaquin River system spend the summer holding in large pools where summer temperatures are usually below 21–25°C (Moyle 1976). Sustained water temperatures above 27°C are lethal to adults (Cramer and Hammack 1952). Pools in which the adults hold are at least 1–3 m deep, with bedrock bottoms and moderate velocities (G. Sato, unpublished data; Marcotte 1984). In Deer Creek, preferred mean water velocities measured in 1988 were 60–80 cm/s for adults (Sato and Moyle 1988). The pools usually have a large bubble curtain at the head, underwater rocky ledges, and shade cover throughout the day (Ekman 1987). The salmon will also seek cover in smaller pocket water behind large rocks in fast water. Habitat preference curves determined by the USFWS for adult chinook in the Trinity River indicate that pool use declines when depths become less than 2.4 m and optimal water velocity ranges from 15 to 37 cm/s (Marcotte 1984).

Spawning occurs in gravel beds that are often located at tails of holding pools. Optimum substrate for embryos is a mixture of gravel and rubble (mean diameter 14 cm) with less than 25% fines (less than 6.4 mm diameter) (Platts et al. 1979, Reiser and Bjornn 1979). Optimal temperatures for development are 5–13°C. Newly emerged fry congregate in shallow, low-velocity edgewater, especially in areas where organic debris provides a background that makes the juveniles difficult to see (Moyle, unpublished data). Juveniles in Deer Creek were found to prefer runs or riffles with gravel substrates, depths of 20–120 cm, and mean water-column velocities of 20–40 cm/s^{-1} (Sato and Moyle 1989).

Occurrence at the Pittsburg and Contra Costa Power Plants: Adult spring-run salmon move past Contra Costa and Pittsburg Power Plants very quickly during their upriver migrations, spending little time within the lower sections of the Sacramento and San Joaquin rivers. Delays in adult migration do not occur as the large adult fish can easily avoid any potential barrier due to the power plants. The smolts may be exposed to the intakes during their downriver migration, but by the time these fish reach the western edge of the Delta, they are headed to the ocean as quickly as possible, minimizing the period of potential exposure

Central Valley Fall/Late Fall-run ESU Chinook Salmon (*Oncorhynchus tshawytscha*)

Status: The Central Valley fall/late fall-run chinook salmon is federally proposed as threatened. The San Joaquin fall-run and Sacramento late fall-run have recently been combined into a single run by NMFS. The following information describes each of the original run types.

San Joaquin Fall-run

Life History: The life history of San Joaquin fall chinook is similar to that of other fall-run salmon. San Joaquin fall chinook generally begin arriving in the system in early fall. Salmon usually begin entering San Joaquin River tributaries by mid-October and are through spawning by mid-December. In the Tuolumne River, most spawning occurs in November, but has been observed from the last week in October through the last week in December (EAEST 1992). Most San Joaquin fall chinook return as 3-year-old fish, but in some years the run may be dominated by male and female 2-year olds ("jacks"), both male and female (EAEST 1992). In the Tuolumne River, the percentage of females in recent years (1971-1988) has ranged from 25 to 67% (EAEST 1992). The number and size of females is regarded as a major factor limiting salmon production

Females select suitable spawning sites on the basis of depth, water velocity, and gravel composition. In the Stanislaus River, spawning occurs at mean depths of about 52 cm and at mean velocities of about 49 cm/s (Aceituno 1993). Females excavate nests, or redds, and eggs are fertilized while being deposited in the nest. Spawning activities generally proceed in an upstream direction so that each successive egg pocket within a redd is covered by gravel from subsequent excavation activities. San Joaquin fall-run chinook females average fecundities of 2,800-6,700 eggs depending on age and size, with the estimated average number of eggs produced by a 3-year-old female being 4,458; the equation for estimating fecundity is 109.4 times fork length (cm) minus 3200.2 (EAEST 1992).

Eggs incubate in the gravel for 10-12 weeks, depending on temperature. Alevins or sac fry then hatch but remain in the gravel for an additional month until the yolk sac is absorbed. Juveniles then emerge and feed on aquatic invertebrates for an additional 8-12 weeks until reaching 75-100 mm FL. From mid-March through early June, juveniles undergo physiological changes (smolting) necessary for transition from a freshwater existence to a saltwater existence and move down tributaries, into the San Joaquin River, and through the Sacramento-San Joaquin estuary to the ocean. In the Stanislaus River, small numbers of juveniles may remain through the summer and appear to emigrate in October or November (CDFG 1992a).

2411

Survival rates of outmigrating smolts from the three tributaries are relatively low due to a combination of factors (EAEST 1992). In the rivers, predation by exotic species (centrarchid basses, etc.) can be a major problem in the lower reaches, especially if flows are low. When flows increase, outmigration time is more rapid and water clarity and temperatures are lower, which decrease the effectiveness of predators. In the San Joaquin River, high temperatures, low oxygen levels, inadequate shallow water habitat (cover), and exotic predators (e.g., striped bass) contribute to high mortality rates. In the Sacramento-San Joaquin Delta, the single biggest cause of mortality is the pumps of the CVP and SWP through direct entrainment, increased predation rates (e.g., Clifton Court Forebay), and movement of smolts to unfavorable habitats, delaying outmigration.

Abundance: Pre-water development population levels of San Joaquin fall chinook are unknown. In 1955, the CDFG estimated that with proper water management the San Joaquin River drainage could still produce 210,00 wild chinook salmon per year with fall chinook as the major run (CDFG 1955); however, production has never approached that level since records have been kept. Annual population surveys have been conducted on all tributaries since 1953 and on some tributaries since 1940. Over this period, populations have fluctuated in abundance. Higher returns of adult fish are strongly correlated with wet years. Similarly, low adult returns are correlated with normal, dry, and critically dry water years. Prior to 1990, spawning populations in the San Joaquin River drainage fell below 2,000 fish just three times (1962, 1963, and 1977). These low adult returns followed previous drought periods that extended for no more than three consecutive brood years. The 1987-1992 drought resulted in adult returns of less than 2,000 fish beginning in 1990 (941 fish in 1990, 717 fish in 1991, and 1,377 fish in 1992) but returns exceeded 2,000 (2,607) in 1993. The general trend in numbers of San Joaquin fall-run chinook has been downward, although large fluctuations in numbers can mask the trend for a number of years (e.g., 1981-1985).

Distribution: Fall chinook salmon are found in rivers from California to Alaska and are now the major run in Central Valley streams. In the San Joaquin River system, San Joaquin fall chinook is the only salmon run remaining because spring chinook were eliminated from the system by the construction of impassable dams on major tributaries; the final extirpation occurred with the closure of Friant Dam on the upper San Joaquin River. At present, San Joaquin fall chinook are restricted to the three major tributaries of the San Joaquin River, the Stanislaus, Tuolumne, and Merced rivers. Within these river systems, spawning is confined to the upstream reaches below the first major dams.

Habitat Requirements: San Joaquin fall chinook require suitable habitat for upstream migration of adults, spawning, and rearing and outmigration of smolts. Requirements of upstream migrating adults include sufficient water flows to attract fish into spawning streams and for upstream passage to spawning areas. During upstream migration, water must be cool enough and have sufficient dissolved oxygen concentrations not to stress adult fish. Adult fish may delay upmigration if these requirements are not met. Spawning adults require gravel beds with gravel of a size that the fish can excavate (optimum is 2-11 cm). Eggs and alevins (sac-fry) require intragravel water flow while in the gravel, which is created when water velocities over the gravel are 30-90 cm/s (Jensen 1972). Water should contain high concentrations of dissolved oxygen and be relatively cool (range of 5-13°C) for proper development of embryos and survival of alevins (Vogel and Marine 1991). Juvenile requirements include sufficient food and low enough temperatures (6-18°C) to allow growth and smoltification. In the lower San Joaquin River, out migrating smolts are found in a wide variety of shallow-water habitats but disappear from these habitats (through death and migration) when temperatures exceed 18°C (McFarland and Weinrich 1987). Sufficient outflows and water temperatures are necessary to ensure survival during outmigration of smolts to the ocean. Both are often lacking in the lower San Joaquin River during the outmigration period.

Occurrence at the Pittsburg and Contra Costa Power Plants: Adult San Joaquin fall-run salmon move past Contra Costa and Pittsburg Power Plants very quickly during their upriver migrations, spending little time within the lower sections of the Sacramento and San Joaquin rivers. Delays in adult migration do not occur because the large adult fish can easily avoid any potential barrier due to the power plants. The smolts may be exposed to the intakes during their downriver migration, but by the time these fish reach the western edge of the Delta, they are headed to the ocean as quickly as possible, minimizing the period of potential exposure.

Sacramento Late Fall-run

Life History: Most of late-fall chinook salmon appear to spawn in the mainstem of the Sacramento River (USFWS 1996), which they enter from October through February (Vogel and Marine 1991). In the past, these migrating fish were a mixture of age classes ranging from 2 to 5 years old. At the present time, most of the fish are 3- and 4-year-olds. While migrating and holding in the river, late-fall chinook do not feed, relying instead on stored body fat reserves for maintenance. Spawning occurs in January, February, and March, although it may extend into April in dry years. Eggs are laid in large depressions (redds) hollowed out in gravel beds. The embryos hatch following a 3- to 4-month incubation period and the alevins (sac-fry) remain in the gravel for another 2-3 weeks. Once their yolk sac is absorbed, the fry emerge and begin feeding on aquatic insects. All fry have emerged by early June. The juveniles hold in the river for about 6 months before moving down to the Delta in October through December. They may hold in the Delta for varying lengths of time, emigrating to the ocean in December through March (USFWS 1996). Once in the ocean, salmon are largely piscivorous and grow rapidly. Because of their relatively large size, late-fall run chinook have the highest fecundity of any of the Sacramento runs of salmon, with females averaging around 6,000 eggs (USFWS 1996).

Abundance: The historic abundance of late-fall chinook is not known because it was formally recognized as distinct from fall-run chinook only after Red Bluff Diversion Dam was constructed in 1966. To get past the dam, salmon migrating up the Sacramento River had to ascend a fish ladder in which they could be counted with some accuracy for the first time. The four chinook salmon runs present in the river (fall, late-fall, winter, and spring) were revealed as peaks in the counts, although salmon passed over the dam during every month of the year. Like winter-run and spring-run chinook, their numbers have declined since counting began in 1967. In the first 10 years of counting (1967-1976), the run averaged about 22,000 fish; in the last 10 years of counting (1982-1991), the run averaged about 9,700 fish (CDFG, unpublished data). There have been no counts of 20,000 fish or more since 1975, although 16,000 fish were counted in 1987. The run in 1991 was 7,089 fish (USFWS 1992). Counts for 1992 and 1993 are not available because the gates at Red Bluff Diversion Dam have been opened to allow free passage for winter-run chinook adults and smolts. Consequently, counting adult migrants is no longer possible.

Distribution: Late-fall chinook are found mainly in the Sacramento River, and most spawning and rearing of juveniles occurs in the reach between Red Bluff and Redding (Keswick Dam). According to Vogel and Marine (1991), however, up to approximately 15-30% of the total late-fall run can spawn downstream of Red Bluff when water quality is good. USFWS (1996) indicated that apparent late-fall chinook have been observed spawning in Battle Creek, Cottonwood Creek, Clear Creek, Mill Creek, Yuba River and Feather River, but these are at best a small fraction of the total population. Battle Creek spawners are presumably derived from an artificially maintained run from the Battle Creek Fish Hatchery. The historic distribution of late-fall run is not known, but it probably originally spawned in the upper Sacramento River and major tributaries in reaches now blocked by Shasta Dam. Some spawning may also have occurred in major tributaries to the San Joaquin River.

Habitat Requirements: The specific habitat requirements of late-fall chinook have not been determined, but they are presumably similar to other chinook salmon runs (see spring-run chinook salmon account) and fall within the range of physical and chemical characteristics of the Sacramento River above Red Bluff.

Occurrence at the Pittsburg and Contra Costa Power Plants: Adult late-fall run salmon move past Contra Costa and Pittsburg Power Plants very quickly during their upriver migrations, spending little time within the lower sections of the Sacramento and San Joaquin rivers. Delays in adult migration do not occur because the large adult fish can easily avoid any potential barrier due to the power plants. The smolts may be exposed to the intakes during their downriver migration, but by the time these fish reach the western edge of the Delta, they are headed to the ocean as quickly as possible, minimizing the period of potential exposure.

Central Valley ESU Steelhead (*Oncorhynchus mykiss*)

Status: Steelhead are listed as threatened under the Federal Endangered Species Act.

Life History: Steelhead are the anadromous form of rainbow trout, a salmonid species native to western North America. Steelhead are born in freshwater, spend 1 to 3 years in their natal streams, and then emigrate to the Pacific ocean where most of their growth occurs. Unlike Pacific salmon, steelhead do not necessarily die after spawning. In the Central Valley, the adults can begin moving through the main stem in July, peak near the end of September, and continue migrating through February or March (Bailey 1954; Hallock et al. 1961). In California, most steelhead spawn from December through April in tributaries and small streams where cool, well oxygenated water is available year-round. Central Valley steelhead move up through the rivers and spawn mainly from January through March (Hallock et al. 1961). The length of time for the eggs to develop is dependent primarily on water temperatures. Fry have been found to emerge from the gravel in four to six weeks (Shapovalov and Taft 1954). Newly emerged fry move to shallow, protected areas associated with the stream margin (Royal 1972; Barnhart 1986). The juveniles soon move to other areas of the stream to establish feeding stations. Some juveniles inhabit riffles but some of the larger individuals will inhabit pools and deeper runs (Barnhart 1986). The smolts can move down through the system to the ocean at any time of the year.

Abundance and Distribution: The California Fish and Wildlife Plan estimated an annual run size of 40,000 adult steelhead for the entire Central Valley (including San Francisco Bay tributaries) for the early 1960s'. The present annual run size in the Central Valley is estimated to be about 10,000 adult fish. Steelhead ranged throughout the tributaries of the Sacramento and San Joaquin rivers prior to dam construction and water development, but present distribution is primarily limited to the Sacramento River and its tributaries. Historically, major steelhead runs occurred in the Feather, Yuba, and American rivers. The overall run is presently a combination of hatchery and wild stocks. The runs on the Upper Sacramento, Feather, American, and Mokelumne rivers are primarily supported by hatchery production, while the wild stocks are confined mostly to relatively small runs in the Yuba River and some upper Sacramento tributaries (Antelope, Deer, and Mill creeks).

Occurrence at the Pittsburg and Contra Costa Power Plants: Steelhead adults move upstream through the Delta and into the Sacramento River at any time from July through March. The adults do not spawn immediately and sometimes remain in the river for up to several months before spawning. During egg incubation and rearing periods for fry and juveniles, cool water temperatures are critical for optimal survival. Juveniles remain in fresh water for 1 to 3 years prior to moving out to the ocean (smolting).

Adult steelhead move past Contra Costa and Pittsburg power plants during their upriver migrations, but spend little time within the lower sections of the Sacramento and San Joaquin rivers, minimizing their exposure to the power plants. Large adult fish can likely avoid any potential barrier due to the power plants. The smolts may be exposed to the intakes during their downriver migration, but by the time these fish reach the western edge of the Delta (usually at 2 years of age), they are also large enough to avoid impacts related to the power plant's intakes and discharges.

Sacramento Splittail (*Pogonichthys macrolepidotus*)

Status: Sacramento splittail is proposed for listing as threatened under the Federal Endangered Species Act.

Life History: Splittail are relatively long-lived (about 5–7 years) and are highly fecund (up to 100,000 eggs per female). Their populations fluctuate on an annual basis depending on spawning success and strength of the year-class (Daniels and Moyle 1983). Male and female splittail mature by the end of their second year, when the fish are about 180–200 mm SL.

There is some variability in the reproductive period, with older fish reproducing first, followed by younger fish that tend to reproduce later in the season (Caywood 1974). The onset of spawning seems to be associated with increasing water temperature and day length and occurs between early March and May in the upper Delta (Caywood 1974). However, Wang (1986) found that in the tidal freshwater and euryhaline habitats of the Sacramento–San Joaquin estuary, spawning can occur by late January/early February and continue through July. Spawning periods are also indicated from salvage records from the State Water Project pumps. Adults are captured most frequently in January through April, when they are presumably engaged in spawning movements, while young-of-the-year are captured most abundantly in May through July (Meng 1993). These records indicate most spawning occurs from February through April.

Splittail spawn on submerged vegetation in flooded areas. Spawning occurs in the lower reaches of rivers (Caywood 1974), dead-end sloughs (Moyle 1976), and in the larger sloughs such as the Montezuma Slough (Wang 1986). Larvae remain in the shallow, weedy areas inshore, close to the spawning sites and move into the deeper offshore habitat as they mature (Wang 1986).

Splittail are benthic foragers that feed extensively on opossum shrimp (*Neomysis mercedis*), although detrital material typically makes up a high percentage of their stomach contents (Daniels and Moyle 1983). They will feed opportunistically on earthworms, clams, insect larvae, and other invertebrates. They are preyed upon by striped bass and other predatory fishes. The preference for splittail by striped bass has long been recognized by anglers.

Abundance: Splittail have disappeared from much of their native range because dams, diversions, and agricultural developments have eliminated or greatly altered much of the lowland habitat. Access to spawning areas or upstream habitats is now blocked by dams such as the Nimbus Dam on the American River and Oroville Dam on the Feather River. Because splittail seem incapable of negotiating existing fishways, they cannot ascend the Sacramento River further than Red Bluff Diversion Dam. They are rarely found more than 10–20 km above the upstream boundaries of the Delta. Caywood (1974) found a consensus among splittail anglers that the fishery had declined since the completion of Folsom and Oroville dams. In the San Joaquin River, their distribution may be limited by poor water quality (high temperature and pollutants) because they seem to move up the river only during wet years.

The principal habitat of splittail is the Sacramento–San Joaquin estuary, especially the Delta. Their abundance in this system is strongly tied to outflows, presumably because spawning occurs over flooded vegetation. When outflows are high, reproductive success is high; but when outflows are low, reproduction tends to fail (Daniels and Moyle 1983).

Even within their constricted range in the Delta, splittail populations are estimated to be only 35%-60% as abundant as they were in 1940 (CDFG 1992b). Since 1980, splittail numbers in the Delta have declined steadily (Moyle et al. 1985), and in 1992, numbers declined to the lowest on record (P. Moyle and CDFG, unpublished data). An analysis of data from four studies conducted in the estuary indicate that splittail have declined by 62% over a 13-year period starting in 1980 (Meng and Moyle 1995). Population levels appear to fluctuate widely from year to year. CDFG midwater trawl data for 1967–1990 indicate a decline from the mid-1960s to the late 1970s, a resurgence (with fluctuations) through the mid-1980s, and a decline since 1986. Survey data for Suisun Marsh (University of California, Davis, unpublished data) show a substantial decline in numbers for 1979–1991 (mean catch in 1979–1983 ca. 188 fish/month, mean catch in 1987–1990 ca. 25 fish/month, mean catch in 1990–1991 ca. 3–5 fish/month). Data from the CDFG Bay-Delta survey and fish salvage operations at the state and federal pumping plants in the south Delta indicate that splittail recruitment success is highly variable from year to year. Large pulses of young fish were observed in 1982, 1983, and 1986, but recruitment was low in 1980, 1984, 1985 and 1987–1990. High numbers of young splittail were also observed in summer 1995, particularly in the south Delta area. This response certainly supports the connection between numbers of young splittail produced and high outflow in the spring. Since 1985, splittail have been rare in San Pablo Bay, reflecting a constriction of their distribution to the upper Bay-Delta areas and to isolated areas like the Petaluma and Napa rivers.

Distribution: The Sacramento splittail is a central California endemic that was once distributed in lakes and rivers throughout the Central Valley. They were found as far north as Redding by Rutter (1908) who collected them at the Battle Creek Fish Hatchery in Shasta County. Splittail are no longer found in this area and seem to be limited by the Red Bluff Diversion Dam in Tehama County to the downstream reaches of the Sacramento River. They also enter the lower reaches of the Feather River on occasion, but records indicate that Rutter (1908) had collected them as far upstream as Oroville. Splittail are also known from the American River and have been collected at the Highway 160 bridge in Sacramento, although Rutter (1908) collected them as far upstream as Folsom. He also collected them from the Merced River at Livingston and from the San Joaquin River at Fort Miller (where Friant Dam is now located). Snyder (1908) reports catches of splittail from southern San Francisco Bay and at the mouth of Coyote Creek in Santa Clara County, but recent surveys indicate that splittail are no longer present in these locations (Leidy 1984).

Splittail are now largely confined to the Delta, Suisun Bay, Suisun Marsh, Napa River, Petaluma River, and other parts of the Sacramento–San Joaquin estuary (Caywood 1974; Moyle 1976; Moyle, unpublished data). In the Delta, they are most abundant in the north and west portions, although other areas may be used for spawning (CDFG 1987). This may reflect a shrinking of their Delta habitat because Turner and Kelley (1966) found a more even distribution throughout the Delta. Recent surveys of San Joaquin Valley streams found small numbers of splittail in the San Joaquin River below its confluence with the Merced River (Saiki 1984); large numbers of juveniles were caught in 1986 in the San Joaquin River 10–12 km above the junction with Tuolumne River (USFWS 1996). Successful spawning has been recorded in the lower Tuolumne River during wet years in the 1980s, with both adults and juveniles observed at Modesto, 11 km upriver from the river mouth (USFWS 1996). Further surveys are needed to determine how far up the San Joaquin River drainage splittail currently migrate for spawning. Occasionally, splittail are caught in San Luis Reservoir (Caywood 1974), which stores water pumped from the Delta. Except when spawning, splittail are largely absent from the Sacramento River. Large individuals are caught during spring in the lower river in large fyke traps set to catch striped bass migrating upstream to spawn (CDFG, unpublished data). Presumably, the splittail are also on a spawning migration. In spring 1993, adult and young-of-the-year splittail were captured in isolated pools in the Sutter and Yolo bypasses (USFWS 1996) and a single individual was captured in Big Chico Creek, Butte County, in 1993 (USFWS, unpublished data).

Habitat Requirements: Splittail are primarily freshwater fish, but are tolerant of moderate salinities and can live in water with salinities of 10–18 ppt (Moyle 1976, unpublished observation). In the 1950s, they were commonly caught by striped bass anglers in Suisun Bay during periods of rising tides (USFWS 1996). During the past 20 years, they have been found mostly in slow-moving sections of rivers and in sloughs and have been most abundant in the Suisun Bay/Marsh region (Meng 1993). They are year-round residents in Suisun Marsh, concentrating in the dead-end sloughs that typically have small streams feeding into them (Daniels and Moyle 1983, Moyle et al. 1985). They tend to be most abundant where other native fishes are abundant. In Suisun Marsh, trawl catches are highest in summer when salinities are 6–10 ppt and temperatures are 15–23°C (Moyle et al. 1985). In Suisun Bay, splittail of all sizes are most consistently found in shallow water at salinities less than 2–3 ppt (Meng 1993). In spring, adult and young-of-the-year splittail are frequently found in shallow, flooded areas such as the Yolo and Sutter bypasses, low-lying parts of Delta islands (e.g., Miller Park), and river mouths. Young-of-the-year and age-1 splittail were common in beach seine sampling by the CDFG in 1993 along the Sacramento River between Rio Vista and Chipps Island (USFWS

1996). Furthermore, in the CDFG Bay Study samples, splittail are more common from stations less than 6.7 m (21 ft) deep. Thus, juvenile splittail may be concentrated in the shallow peripheries of the Sacramento River, and they may be more abundant there than indicated by sampling done to date (USFWS 1996).

Daniels and Moyle (1983) found that year-class success in splittail was positively correlated with Delta outflow, and Caywood (1974) found that a successful year-class was associated with winter runoff sufficiently high to flood the peripheral areas of the Delta. These observations were confirmed by the analysis of the state (CDFG 1992b). Meng (1993) found a strong negative relationship between amount of water diverted from the Delta and abundance of young splittail, noting that the effect of diversions seemed to be particularly strong in dry years.

Occurrence at the Pittsburg and Contra Costa Power Plants: All life stages of Sacramento splittail occur in the vicinity of the Contra Costa and Pittsburg Power Plants. Their abundance is dependent on the type of water year (i.e., the amount of freshwater outflow). In wet years, when freshwater conditions prevail for longer periods of time, larger numbers of splittail, particularly juveniles and larvae, are expected in the vicinity of the plants. Thus, during wet years, juvenile splittail are more susceptible to impingement at the intake screens, and larval spittail are more susceptible to entrainment in the circulating water system.

Green Sturgeon (*Acipenser medirostris*)

Status: The green sturgeon has no official state or Federal status.

Life History: The ecology and life history of green sturgeon have received little study. The adults are more marine than white sturgeon, spending limited time in estuaries or freshwater. In the Klamath River system, green sturgeon migrate up-river between late February and late July. The spawning period is March–July, with a peak from mid-April to mid-June (Emmett et al. 1991). Spawning times in the Sacramento River are probably similar. Spawning occurs in deep, fast water. In the Klamath River, a pool known as "The Sturgeon Hole" (1.5 km upstream from Orleans, Humboldt County) apparently is a major spawning site, because leaping and other behavior indicative of courtship and spawning are often observed there during spring and early summer (Moyle 1976). Female green sturgeon produce 60,000–140,000 eggs (Moyle 1976), each being about 3.8 mm in diameter. Based on their presumed similarity to white sturgeon, green sturgeon eggs probably hatch about 196 hours (at 12.7°C) after spawning. Juveniles migrate out to sea before 2 years of age, primarily during the summer-fall period (Emmett et al. 1991). Length-frequency analyses of sturgeon caught in the Klamath estuary in beach seines indicate that most green sturgeon leave the system at lengths of 30–70 cm. Individuals tagged by the CDFG in San Pablo Bay (part of the San Francisco Bay system) have been recaptured off Santa Cruz, in Winchester Bay on the southern Oregon coast, at the mouth of the Columbia River, and in Gray's Harbor, Washington (Chadwick 1959, Miller 1972).

Green sturgeon grow approximately 7 cm per year until they reach maturity at 130–140 cm, about age 15–20 (USFWS 1982). Growth slows after they reach maturity, and maximum size in the Klamath River in recent years has been around 230 cm (USFWS 1982). The largest fish have been aged at 40 years, but this is probably an underestimate (USFWS 1996). The largest green sturgeon are typically females, and virtually all fish over 200 cm are female (USFWS 1982).

Juveniles and adults are benthic feeders and may also take small fish. Juveniles in the Sacramento–San Joaquin Delta feed on opossum shrimp (*Neomysis mercedis)* and amphipods (*Corophium* sp.) (Radtke 1966). Adult sturgeon caught in Washington feed mainly on sand lances (*Ammodytes hexapterus*) and callianassid shrimp (P. Foley, UCD, unpublished data).

Abundance: In California, green sturgeon have been collected in small numbers in marine waters from the Mexican border to the Oregon border. They have been noted in a number of rivers, but spawning populations are known only in the Sacramento and Klamath rivers.

The San Francisco Bay system, comprising San Francisco Bay, San Pablo Bay, Suisun Bay, and the Delta, is home to the southernmost reproducing population of green sturgeon. Green sturgeon were originally described from San Francisco (Ayres 1854). White sturgeon are the most abundant sturgeon in this system, and green sturgeon have always been comparatively uncommon (Ayres 1854, Jordan and Gilbert 1883). Intermittent studies by the CDFG between 1954 and 1991 have measured and identified 15,901 sturgeon of both species. Based on these data, a green sturgeon to white sturgeon ratio of 1:9 was derived for fish less than 101 cm FL and 1:76 for fish greater than 101 cm FL (USFWS 1996). If it is assumed that green sturgeon and white sturgeon are equally vulnerable to capture by various gear and that the CDFG population estimates of white sturgeon (11,000–128,000, depending on the year) are accurate (Kohlhorst et al. 1991), then the number of green sturgeon longer than 102 cm has ranged from 200 to 1,800 fish in the estuary (USFWS 1996). These numbers should be regarded as very rough estimates because the above assumptions are uncertain.

Numbers of juvenile green sturgeon are more variable than numbers of adults since reproduction is presumably episodic (Kohlhorst et al. 1991). One indication of this is the numbers of green sturgeon (mostly juveniles) salvaged at the pumps of the SWP and CVP in the south Delta. Between 1979 and 1991, 6,341 fish identified as green sturgeon were captured at the two facilities combined; 32,708 white sturgeon were identified in the same period. Annual numbers ranged from 45 (1991) to 1,476 (1983). Other high salvage years were 1982 (1,093) and 1985 (1,377). However, these data are not very reliable because of poor quality control on both counts and species identification (USFWS 1996). In addition, juvenile sturgeon are probably more vulnerable to entrainment at low or intermediate outflows.

Indirect evidence indicates that green sturgeon spawn mainly in the Sacramento River. They have been reported in the mainstem Sacramento River as far north as Red Bluff, Tehama County (river km 383) (Fry 1979). Young green sturgeon have been taken near Hamilton City, Glenn County (Fry 1979). Additionally, four young green sturgeon were collected at the Red Bluff Diversion Dam in late October 1991 (USFWS 1996). River guides have taken adult green sturgeon at the Anderson Hole, about 6 km above the Hamilton Bridge (USFWS 1996). A dead adult green sturgeon was found on April 18, 1991, approximately 5 km south of Dairyville, Tehama County (USFWS 1996). Live adult green sturgeon have been observed by USFWS crews surveying winter-run chinook salmon (*Oncorhynchus tshawytscha*) in the 16-km reach of river below Red Bluff Diversion Dam in 1991 and 1992 (USFWS 1996). In 1991, 20 large sturgeon were sighted in this area between April 3 and May 21. Pat Foley of the University of California, Davis reported recent photographs of green sturgeon taken by sportfishers in the Feather River, a tributary of the Sacramento. It is possible that some spawning may occur in the San Joaquin River, because young green sturgeon have been taken at Santa Clara Shoal, Brannan

Island State Recreational Area, Sacramento County (Radtke 1966), and a single specimen from Old River is in the California Academy of Science collection (USFWS 1996).

Distribution: In North America, the green sturgeon ranges in the ocean from the Bering Sea to Ensenada, Mexico, a range that includes the entire coast of California. They have been found in rivers from British Columbia south to the Sacramento River in California. There is no evidence of green sturgeon spawning in Canada or Alaska, although small numbers have been caught in the Fraser and Skeena rivers, British Columbia (Houston 1988). Green sturgeon are particularly abundant in the Columbia River estuary, and individuals have been observed 225 km inland in the Columbia River (Wydoski and Whitney 1979); they are currently found almost exclusively in the lower 60 km and do not occur upstream of Bonneville Dam (Oregon Department of Fish and Wildlife 1991). There is no evidence of spawning in the Columbia River or other rivers in Washington. In Oregon, juvenile green sturgeon have been found in several of the coastal rivers (Emmett et al. 1991), but spawning has only been confirmed in the Rogue River (A. Smith, minutes to USFWS meeting on green sturgeon, Arcata, California, May 3, 1990; P. Foley, UCD, unpublished notes). In California, green sturgeon spawning has been confirmed in recent years only in the Sacramento and Klamath rivers, although spawning probably once occurred in the Eel River as well (Moyle et al. 1993).

Habitat Requirements: Habitat requirements of green sturgeon are not well known, but spawning and larval ecology probably are similar to that of white sturgeon. Comparatively large egg size, thin chorionic layer on the egg, and other characteristics indicate that green sturgeon probably require colder, cleaner water for spawning than white sturgeon (USFWS 1996). In the Sacramento River, adult sturgeon are in the river, presumably spawning, when temperatures range between 8 and 14°C. Preferred spawning substrate is large cobble, but can range from clean sand to bedrock. Eggs are broadcast-spawned and externally fertilized in relatively high water velocities and probably at depths >3 m (Emmett et al. 1991). The importance of water quality is uncertain, but silt is known to prevent eggs from adhering to each other.

Occurrence at the Pittsburg and Contra Costa Power Plants: Green sturgeon occur in the vicinity of the Contra Costa and Pittsburg Power Plants as adults during upriver spawning migrations in the spring, and as juvenile fish either moving downriver to the marine system or utilizing the western Delta area as rearing habitat. Adults and juvenile fish are large enough to easily avoid the power plant intakes.

Soft Bird's-Beak (*Cordylanthus mollis* ssp. *mollis*)

Status: This plant is proposed for listing as endangered by the USFWS, is listed as rare by the CDFG, and is considered rare, threatened, or endangered throughout its range by the California Native Plant Society (Skinner and Pavlik 1994).

Description: The soft bird's-beak is a member of the Scrophulariaceae (figwort or snapdragon) family. This annual plant is 20-40 cm tall and well branched. The leaves and bracts are pale green, with the lower leaves entire, oblong, 0.5-1 cm long and the upper leaves broader, 1-2 cm long, with 1-2 pairs of small lobes. The flowers are 16-17 mm long, the lower lip with a yellowish-pubescent pouch and rounded glabrous lobes. Flowering time is from July to November.

Habitat: It is found in the intertidal zone of coastal marshes.

Occurrence at the Pittsburg and Contra Costa Power Plants and Montezuma Habitat Enhancement Site: A single population of soft bird's-beak was found during surveys conducted adjacent to the Pittsburg Power Plant in 1992. No populations of soft bird's-beak were found during surveys conducted in the vicinity of the Montezuma site in 1973-1974 (Jones & Stokes, Inc., 1975) or 1977-1978 (BioSystems Analysis, Inc., 1980)

California Black Rail (*Laterallus jamaicensis coturniculus*)

Status: The California black rail is listed as threatened by the CDFG.

Description: The California black rail is a sparrow-sized bird (about 12.5 cm total length), uniformly slate-gray overall except for variable amounts of white spotting on the back and sides, and has chestnut coloration on the nape of the neck. The bill is blackish, legs and toes blackish-brown, and the eyes are reddish-brown. Sexes are similar in appearance, and juveniles apparently differ only in more uniform coloration and less distinctive pattern.

The first known specimen of the California black rail was presented to the Smithsonian Institution in 1859 (Wilbur 1974a). The collecting locality was given as "Farallones, Cal." apparently referring to the Farallon Islands, about 30 miles west of San Francisco. No collecting date or additional data were included with the specimen. It was described by Ridgway (1874) as the Farallon rail (*Porzana jamaicensis coturniculus*). Controversy arose over the identity of the bird when black rails were discovered on the nearby California mainland. After numerous name changes, the California black rail was classified as the subspecies, *Creciscus jamaicensis coturniculus*. Peters (1934) placed the North American black rails in the genus *Laterallus*, where they remain to date.

Distribution: The California black rail historically was known or thought to occur as a breeder from the San Francisco Bay Area (including the Sacramento/San Joaquin Delta) south along the coast to northern Baja California, in the San Bernardino/Riverside area, at the Salton Sea, and along the lower Colorado River north of Yuma in California and Arizona. The coastal populations included ones at Morro Bay and San Diego. Wintering birds were found in the breeding areas and were also found at Tomales Bay. The current distribution of the California black rail differs from the historic known range; the breeding range has been reduced as a result of wetland loss. The California black rail is probably absent as a breeder from coastal and southern California and from south San Francisco Bay. They evidently breed at Morro Bay, but the breeding status in the Riverside area is unknown. Breeding birds have been identified in Tomales Bay, Bolinas Lagoon, Corte Madera Marsh, Gallinas Creek, Novato Creek, Day Island, Green Point, Midshipman Point, Ryer Island, Roe Island, San Pablo Marsh Creek, and the marshes at China Camp, Black John Slough, Petaluma River, and Sonoma Creek.

Abundance: The major breeding population appears to be in the north San Francisco Bay, where the marshes support at least 3,300 black rails (Evens et al. 1986). Evens (1987) believes it is likely that the Petaluma Marsh supports the bulk of the remaining breeding population of black rails in California, with densities of 3.89-4.46 per hectare.

Habitat and Life History: Information on the life history of California black rails is extremely limited. Although first described as birds of the coastal salt marshes, they have since been found regularly in saltwater and freshwater marshes (Wilbur 1974a). Vegetation inhabited varies from almost pure pickleweed (*Salicornia virginica*) along the coast to sedges (*Carex* sp.), saltgrass (*Distichlis spicata*), and bulrush (*Scirpus* sp.) in inland areas. They are usually found in the immediate vicinity of tidal sloughs (Manolis 1977), typically in the high wetland areas near the upper limit of tidal flooding. In sampling salt marshes to determine California black rail habitat preference, Evens (1987) found four factors useful in predicting their presence; vegetation averaging 44 cm in height, the presence of alkali heath (*Frankenia salina*), the presence of insects, and the absence of amphipods. Each of these characteristics is associated with high-elevation marsh.

Nesting occurs from March to early June (Bent 1926, Wilbur 1974a). The nest is loosely made but deeply cupped and almost always completely concealed by surrounding vegetation (Ingersoll 1909, Huey 1916, Hanna 1935). It may be placed on damp ground (Hanna 1935) or elevated in vegetation (Wilbur 1974a). Ingersoll (1909) reports nests up to 15 inches above the ground. Most appear to be only slightly above ground or at water level and may be disturbed by high tides (Wilbur 1974a). Huey (1916) observed nests rebuilt several times after high tides, and Ingersoll (1909) reports many black rail eggs floating in the marsh following high tides.

Heaton (1937b) describes California black rails as hatching one at a time, with the hatched chicks leaving the nest almost immediately, and one of the adult birds keeping all chicks together until hatching is completed. Heaton (1937a) also notes the rails' tendency to desert a nest if disturbed before laying begins and to desert "nine out of ten times" if only one egg has been laid when disturbance occurs. Similarly, Huey (1916) writes of the "astonishing ease" with which these birds abandon incomplete clutches, even if the nest is not actually molested but only approached.

California black rails glean isopods, insects, and other arthropods from the surface of mud and vegetation (Zeiner et al. 1990). The major threat to the continued existence of the California black rail in California has been, and currently is, the loss or degradation of its wetland habitat. In coastal southern California and the San Francisco Bay Area, habitat continues to be lost to filling, subsidence, changes in salinity, and sedimentation. Habitat in the Delta is threatened by decreasing water quality, flooding, and levee maintenance activities. In the San Francisco Bay area, the lack of high marsh vegetation as escape cover and nesting habitat contributes to an abnormally high rate of predation by raptors and ardeids during extreme high tides (Evens and Page 1986) and to the flooding of nests during high tides.

Occurrence at the Pittsburg and Contra Costa Power Plants and the Montezuma Habitat Enhancement Site: According to California Natural Diversity Data Base records, California black rails were last observed on Mallard Island (adjacent to the Pittsburg Power Plant) in 1977. No populations of California black rail were found during surveys conducted in the vicinity of the Montezuma site in 1973-1974 (Jones & Stokes, Inc., 1975) or 1975-1978 (Ficket 1976, BioSystems Analysis, Inc., 1980).

California Clapper Rail (*Rallus longirostris obsoletus*)

Status: The California clapper rail was declared endangered by the USFWS in 1970, and by the CDFG in 1971.

Description: The clapper rail is one of the largest species of the genus *Rallus*, measuring 32-47 cm from tip of bill to tail (Ripley 1977). It has a hen-like appearance, strong legs with long toes, a long, slightly decurved bill, and white undertail coverts that are often exposed when the bird is agitated. The California clapper rail has a cinnamon-buff colored breast and dark flanks crossed by white bars and olive-brown upper body parts.

Distribution: The salt marshes of south San Francisco Bay, including portions of San Mateo, Santa Clara, and Alameda counties, historically supported the largest populations of California clapper rails (Grinnell 1915, Grinnell and Miller 1944). Clapper rails occurred in San Francisco County prior to the 1880s (Gill 1979). Small populations also existed along western Contra Costa County (Grinnell and Wythe 1927, Grinnell and Miller 1944, and Gill 1979). The number of clapper rails along eastern Marin County apparently fluctuated from the 1880s onward (Grinnell 1915, Grinnell et al. 1918); breeding records increased after the 1920s (Grinnell and Wythe 1927, Gill 1979). Grinnell (1915) describes the species as occurring casually near Petaluma, Sonoma County. Gill (1979) discovered very few historic records for Napa Marsh in western Napa County and believed the eastern limit of the California clapper rail was Southampton Bay, Solano County, as reported by Grinnell and Miller (1944). Gill (1979) found no historic records for other parts of Solano County including Suisun Marsh.

Marshes south of San Francisco Bay in Elkhorn Slough, Monterey County, and other marshes adjacent to Monterey Bay were cited by Silliman (1915) as regularly supporting small numbers of California clapper rails. Prior to 1908, Elkhorn Slough had limited tidal access to Monterey Bay and may not have been suitable for clapper rails (Browning 1972).

There are numerous records for Tomales Bay, Marin County, and small marshes along the outer San Mateo County coast (Grinnell and Miller 1944, Gill 1979).

Outside of the San Francisco and Monterey bay areas, reports as early as 1932 stated that clapper rails nested in Humboldt Bay, Humboldt County (Gill 1979), but there are no authenticated records since 1947 (Wilbur and Tomlinson 1976). Brooks (1940) reports a possible breeding population of at least five rails considered to be California clapper rails in Morro Bay, San Luis Obispo County. Despite a 1977 record for Morro Bay (Gill 1979), Harvey (1980a) found no evidence of clapper rails there in 1979.

Since the mid-1880s, 79% or 583 km^2 of the original tidal marshlands of the San Francisco Bay Area have been eliminated through diking, filling, or conversion to salt evaporation ponds (Jones & Stokes et al. 1979). In South San Francisco Bay, clapper rail populations occur in remnant salt marshes such as Bair and Greco Islands (San Mateo County), Dumbarton Point (Alameda County), and in Santa Clara County (USFWS et al. 1984). In San Mateo County, rails can be found as far north as San Bruno Point (Gill 1979). Clapper rails can also be found in salt marshes fringing the South Bay outboard of the salt evaporation pond levees and along major tidal sloughs. Scattered remnant populations primarily occur near creek mouths in northern Alameda County, western Contra Costa County, and in eastern Marin County (USFWS et al. 1984).

In northern San Pablo Bay, clapper rails are resident and breed along the Petaluma River as far north as Schultz Creek and along most major tidal sloughs and creeks in Sonoma and Napa counties (Gill 1979). They also occur north to Bull Island on the Napa River (USFWS et al. 1984). Gill (1979) believes the Napa Marsh clapper rail population became established after 1940, when substantial decreases in freshwater inflow to the marsh resulted in a shift from a freshwater to a brackish marsh.

Gill (1979) predicts that clapper rails would extend their range into Suisun Marsh, Solano County, and northern Contra Costa County if reductions in the Sacramento-San Joaquin Delta outflow continued. Surveys by Harvey (1980a) confirmed that a population of at least 25 rails was present through the 1979 breeding season near Joice and Grizzly islands in Suisun Marsh. A late April record in 1979 at Martinez, Contra Costa County (Harvey 1980a), may also be evidence of breeding.

At least two pairs of clapper rails were discovered in Elkhorn Slough, Monterey County, during recent breeding season surveys (Harvey 1980a), and a minimum of two young were known to have been produced. This is the first verification of nesting at this location since 1972 (Varoujean 1973), but the status of this rail population is unclear. Clapper rails may still occur in Humboldt County or Morro Bay, San Luis Obispo County, as vagrants (Gill 1979).

Habitat and Life History: Throughout their distribution, California clapper rails occur within a range of salt and brackish marshes (Harvey et al. 1977). In South and Central San Francisco Bay and along the perimeter of San Pablo Bay, rails typically inhabit salt marshes dominated by pickleweed (*Salicornia virginica*) and cordgrass (*Spartina foliosa*). Other halophytes usually present include gum-plant (*Grindelia* sp.), salt grass (*Distichlis spicata*), jaumea (*Jaumea carnosa*), and alkali heath (*Frankenia salina*). Brackish water marshes supporting clapper rails occur along major sloughs and rivers of San Pablo Bay and along tidal sloughs of Suisun Marsh. Pickleweed has become more widespread in Suisun Marsh and will increase in abundance if salinity continues to rise (Harvey et al. 1977). This, combined with changes in the invertebrate marsh fauna, may account for the recent establishment of clapper rails in the region. Within a marsh, clapper rails use networks of small tidal sloughs as foraging habitat. California clapper rails have not been recorded in nontidal marsh areas (USFWS et al. 1984).

Throughout the range of the California clapper rail, loss of upper marsh vegetation has greatly reduced available habitat. Most marshes in South San Francisco Bay are adjacent to steep earthen levees that have eliminated upper marsh vegetation and reduced available cover for rails during winter flood tides. High marsh vegetation in Suisun Marsh has also been eliminated by diking and livestock grazing. Recent estimates are for a population of as few as 300 individuals, with over 90% of the populations in south San Francisco Bay (CDFG 1991).

The California clapper rail is secretive and difficult to flush in dense vegetation, but once flushed, can frequently be closely approached. Individuals accustomed to the presence of humans, such as those at the City of Palo Alto Baylands, tolerate people on nearby boardwalks (USFWS et al. 1984). When evading discovery, rails typically freeze or run through vegetation, hunched over with their necks outstretched and plumage compacted, rather than taking flight. When flushed, clapper rails normally fly only a short distance before landing.

There is no clear evidence of migratory behavior in the California clapper rail, and the extent to which movements occur between different marshes is unknown (USFWS et al. 1984). Numerous accounts exist of juveniles dispersing widely from typical breeding habitat (USFWS et al. 1984).

Most nesting surveys of the California clapper rail have been conducted in south or central San Francisco Bay. According to DeGroot (1927), nesting begins in mid-March and extends into July. Two peaks in nesting activity occur: late April to late May and late June to early July (DeGroot 1927, Applegarth 1938, Gill 1972, and Harvey 1980b). The second nesting peak has been interpreted as late nesters (DeGroot 1927) or second attempts after initial nesting failures (Gill 1972). Estimates of clutch size range from 5.83 (Gill 1972) to 8.51 (DeGroot 1927), with observed clutch sizes ranging from 5 to 14 eggs. Both sexes share in incubation, which lasts from 23 to 29 days (Applegarth 1938, Zucca 1954). Eggs are approximately 45 mm in length and light tan or buff-colored with cinnamon-brown or dark lavender spotting concentrated at the broader end.

Clapper rails construct their nests near small tidal sloughs and use existing vegetation or drift material as a canopy over the nest platform. Cordgrass, pickleweed, gum-plant, salt grass, and drift material have been reported as providing nest canopies (Degroot 1927, Zucca 1954, Gill 1972, Harvey 1980b). Even though pickleweed was the main component of nests found by

Harvey (1980b), most nests and calling pairs were within the cordgrass zones of south San Francisco Bay marshes. Gill (1972) calculated higher summer densities of rails in habitat that was dominated by cordgrass.

California clapper rails also build "brood" nests, consisting of a platform of stems without a canopy, to serve as high-tide refuges for young rails (Harvey 1980b). During breeding surveys of south San Francisco Bay and eastern Marin County, a total of 67 nests were found as close as 1.5 m and as far as 11 m from tidal sloughs ranging in width from 0.3 to 10 m. These tidal channels provide clapper rails with a protected route for movement within the marsh, as well as easily accessible foraging habitat and a nearby avenue of escape, particularly for vulnerable flightless young.

Estimates of breeding success in western clapper rail subspecies have been limited to monitoring percent hatching success or percent nest success. Predation of eggs and chicks by the Norway rat (*Rattus norvegicus*) and inundation of nests by high tides have been reported as causing nesting failure (Grinnell et al. 1918, DeGroot 1927, Applegarth 1938, Zucca 1954). Zucca (1954) found that abandoned or disrupted nests were most commonly subject to rat predation. He also believed cordgrass and gum-plant nests were disrupted by tides exceeding +6.7 ft. During the 1980 breeding season, Harvey (1980b) reported a 38% hatching success for 31 California clapper rail nests. He also found that 28 of 50 nests successfully hatched most of their eggs (56% nest success). Fledging success is unknown in the California clapper rail and is extremely difficult to estimate in any clapper rail population.

In summary, the most intensive nesting activity of the California clapper rail occurs from mid-March through July and the most heavily used portions of the San Francisco Bay salt marshes are the lower cordgrass-dominated areas within 10 m of tidal sloughs. During the winter, rails may be more widely distributed in marshes and more dependent on upper marsh vegetation for cover, particularly during extreme high tides.

The food habits of California clapper rails in south San Francisco Bay are described by Moffitt (1941), who reports that 18 rail stomachs contained 85.5% animal matter. The four major food items were the introduced horse mussel (*Ischadium demissus*), spiders, clams (*Macoma balthica*), and yellow shore crabs (*Hemigrapsus oregonensis*). Williams (1929) also reports clams as being a principal prey species, while Test and Test (1942) found amphipods in the esophagus of a California clapper rail. At the Elkhorn Slough, Monterey County, Varoujean (1973) observed rails feeding on the striped shore crab (*Pachygrapsus crassipes*). The food habits of clapper rails in upper San Pablo Bay and Suisun Marsh are unknown.

Adult clapper rails are taken by several avian predators, including the northern harrier (*Circus cyaneus*), red-tailed hawk (*Buteo jamaicensis*), and peregrine falcon (*Falco peregrinus*). Downy young and eggs are also vulnerable to predation by Norway rats (Harvey 1980b). The introduced horse mussel may cause some mortality by inadvertently trapping the bills or feet of birds that have stepped on or probed into the shell (DeGroot 1927).

Abundance: Overharvesting by commercial and sport hunting during 1850-1913 initially contributed to the depletion of the California clapper rail population (USFWS et al. 1984). After the enactment of the Migratory Bird Treaty Act in 1913, rails regained much of their abundance in the remaining San Francisco Bay marshes (Bryant 1915, Grinnell and Miller 1944). Destruction of habitat, however, continued to reduce local clapper rail populations. The lack of extensive high marsh habitat and the presence of steep earthen levees at most marshes limit potential population expansion. With its relatively limited geographical range, the California clapper rail is also vulnerable to the threats of oil spills and other sources of chemical pollution.

Occurrence at the Pittsburg and Contra Costa Power Plants and the Montezuma Habitat Enhancement Site: No California clapper rails were observed during surveys conducted in the vicinity of the Montezuma site in 1973-1974 (Jones & Stokes, Inc., 1975) or 1975-1978 (Fickett 1976, BioSystems Analysis, Inc., 1980).

California Least Tern (*Sterna antillarum browni*)

Status: The California subspecies is listed as endangered by both the USFWS and CDFG.

Description: Least terns are the smallest American terns, measuring from 21.6 to 24.1 cm long and having a wingspan of about 51 cm. The three U.S. subspecies are virtually indistinguishable morphologically and are currently distinguished by the separation of their breeding ranges (Burleigh and Lowery 1942, Massey 1976, Boyd 1983). Least terns have a black-capped crown, white forehead, black-tipped yellow bill, gray back and dorsal wings, white belly, and orange legs. Juveniles tend to have darker plumage and bill compared to adults and tend to have a dark eye stripe on their white forehead (USFWS 1984). The sexes are virtually identical.

Distribution: The California least tern is migratory, usually arriving in its breeding area during the last week of April and departing again in August (Davis 1968, Swickard 1971, Massey 1974). However, least terns have been recorded in the breeding range as early as March 13 and as late as November 24 (Sibley 1952, USFWS 1980). The historical breeding range of the California least tern has usually been described as extending along the Pacific coast from Moss Landing, Monterey County, California, to San Jose del Cabo, southern Baja California. However, since 1970, nesting sites have been recorded from San Francisco Bay south to Bahia de Quintin, Baja California (USFWS 1980). The nesting range in California has apparently always been widely discontinuous, with most of the birds nesting in southern California from Santa Barbara County south through San Diego County.

The migration routes and winter distribution of the California least tern are little known. There appears to be no confirmed records of least terns on the Pacific coast of South America, and there are only a few reports from the Pacific coast in Honduras, Guatemala, and Panama (USFWS 1980). Because several races of least terns are recognized in western Mexico and most subspecific plumage differences are observable only in breeding plumage, racial allocation of wintering birds is seldom possible without banding or special, readily discernable markings done prior to migration.

Habitat and Life History: Least terns arrive in the vicinity of the nesting areas from mid-April to early May. Some pair bonds may form before arrival in the nesting areas, others begin to form within the group almost immediately, and active courtship may be observed within the first few days after arrival (Davis 1968, Swickard 1971, Massey 1974). Courtship follows a well-defined pattern, beginning with "fish-flights," where a male carrying a fish is joined by one or two other terns in high-flying aerial display. Aerial glides (pairs flying in unison) follow. Posturing and parading on the ground occur in the late stage of courtship, with the male holding a small fish in his beak as he courts the female. During copulation, the female takes the fish from the male and eats it (Wolk 1954, Hardy 1957, Davis 1968, Massey 1974).

The least tern usually chooses its nesting location in an open expanse of light-colored sand, dirt, gravel, or dried mud close to a lagoon or an estuary where food can be obtained (Craig 1971, Swickard 1971, Massey 1974). Formerly, sandy ocean beaches were regularly used, but increased human activity on the beaches has made most of them unpreferred nesting sites. Nest have been observed on mud and sand flats back from the ocean or on manmade landfills (Longhurst 1969, Craig 1971). Least terns are colonial but do not nest in as dense concentrations as many other terns. Although nests have been found as close as 2.5 ft (Davis 1968), usual minimum distances between nests are 10-15 ft, with averages usually much greater (Wolk 1954, Hardy 1957, Massey 1974). Swickard (1971) found nest densities to be 16-18 per acre. In other instances, colonies are widely dispersed with over 300 ft between nests (USFWS 1980).

The nest is a small depression in which eggs are deposited. In sand, it is scooped out by the bird (Davis 1968, Swickard 1971, Massey 1974), but in hard substrates it may be any kind of natural or artificial depression. After the eggs are laid, the nests are often lined with shell fragments and small pebbles.

Least tern eggs measure about 31 x 24 mm and are buffy with various brownish and purplish streaks and speckles (Bent 1921, Hardy 1957, Davis 1968, Massey 1974). One to four eggs are laid, with two- to three-egg clutches being reported most often (Anderson 1970, Massey 1974). Egg laying usually occurs in the morning, and the eggs laid on consecutive days (Davis 1968, Massey 1974). The nesting season extends from approximately mid-May into early August, with most of the nests completed by mid-June (Grinnel 1868, Bent 1921, Swickard 1971). July and August nests may be renests after initial attempts have failed. Most authorities agree that least terns are capable of successfully raising only one brood per pair in a season (USFWS 1980).

Incubation, which begins with the laying of the first egg, is irregular at first but becomes steady after the clutch is completed (Davis 1968, Swickard 1971, Massey, 1974). Both parents participate, but the female initially takes a much greater part than the male (Hagar 1937, Hardy 1957, Davis 1968, Swickard 1971, Massey 1974). Extremes of 17-28 days to complete incubation have been documented (USFWS 1980).

Eggs usually hatch on consecutive days, and the chicks are initially weak and helpless. The adults brood continuously during the first day (Davis 1968), but by the second day, the chicks are strong and make short walking trips from the nest. From the third day on, they are increasingly mobile and active (Davis 1968, Massey 1974). Flight stage is reached at approximately 20 days of age, but the young birds do not become fully proficient fishers until after they migrate from the breeding grounds. Consequently, the parents continue to feed the young even after they are strong fliers (Tompkins 1959, Swickard 1971, Massey 1974).

Although California least tern colonies have sometimes suffered heavy losses of eggs and young to predators or unfavorable weather conditions, egg hatch and nestling survival are generally high. Swickard (1971), and Massey (1974) report 80-90% hatching success. Infertility appears to be a minor cause of least tern egg failure. Predators include the Norway rat, striped skunk (*Mephitus mephitus*), longtail weasel (*Mustela frenata*), common crow (*Corvus brachyrhynchos*), red fox (*Vulpes fulva*), gulls (*Larus* sp.), and domestic dogs.

Fledging rates vary greatly from colony to colony and from year to year (Swickard 1971, Massey 1974). The overall success rate (percent of eggs resulting in flying young) observed in a major colony is about 70% (Massey and Atwood 1979). Loss of tern chicks has been attributed to the American kestrel (*Falco sparverius*), loggerhead shrike (*Lanius ludovicianus*), common crow, common raven (*Corvus corax*), red fox, domestic dogs and cats, inclement weather, dehydration, and starvation.

Banded least terns have been recovered at up to 21 years of age, with 31 of 61 individuals being at least 5 years old (Massey and Atwood 1979). This suggests a relatively long life for individuals of this species. Banding studies have demonstrated that the usual age of first breeding is 3 years, but least terns occasionally breed at age 2 (USFWS 1980).

The California least tern obtains most of its food from shallow estuaries and lagoons, but colonies occasionally forage offshore in the ocean. The California least tern has not been observed eating anything but fish (Massey 1974). Fish known to be eaten, in order of importance, are northern anchovy (*Engraulis mordax*), topsmelt (*Atherinops affinis*), various surf perch (Embiotocidae), killifish (*Fundulus parvipinnis*), mosquitofish (*Gambusia affinis*), and other species (USFWS 1980).

Abundance: The loss of nesting and feeding habitat and high levels of human disturbance at remaining colonies has been responsible for the continued decline of the California least tern population. Formerly nesting in colonies of up to thousands of birds, the total number of breeders found in California in the mid-1970s was only about 600 pairs (CDFG 1991). During the past decade, population status has been stable. Through protection and site management, they increased from about 800 pairs in 1978 to 1,200-1,300 in 1983 (CDFG 1991). They declined to about 1,000 pairs from 1984 to 1987, possibly because of a reduced forage supply caused by El Nino conditions. The population increased again to about 1,200-1,300 pairs in 1988-1990, distributed in 28-29 colonies in the San Francisco Bay Area and from San Luis Obispo County to the Mexican border (CDFG 1991). Habitat preservation, restoration, and creation, along with nesting colony protection, are the major objectives identified by the USFWS California Least Tern Recovery Plan.

Occurrence at the Pittsburg and Contra Costa Power Plants: California least terns have been nesting at PG&E's Pittsburg Power Plant (along the access road to the Unit 7 cooling towers within the cooling water canal) since at least 1984. In 1994, two nesting pair produced three young. In 1995, three pair fledged two chicks, and four pair fledged four chicks in 1996.

Salt Marsh Harvest Mouse (*Reithrodontomys raviventris*)

Status: The salt marsh harvest mouse was declared endangered by the USFWS in 1970 and by the CDFG in 1971.

Description: Salt marsh harvest mice are small native rodents that look like the much more widely distributed western harvest mouse (*Reithrodontomys megalotis*) from which they may have evolved (Fisler 1965). There are two subspecies, the northern (*R. raviventris halicoetes*) in the marshes of the San Pablo and Suisun bays and the southern (*R. r. raviventris*) in the marshes of Corte Madera, Richmond and south San Francisco Bay.

Salt marsh harvest mice are very small cricetid rodents, weighing an average of 10 grams. This mouse has a head and body length of 69-74 mm, a tail length of 65-82 mm, a tail to body ratio of 94-125% and a hind foot length of 17-18 mm (Fisler 1965). When compared to western harvest mice, salt marsh harvest mice have darker ears and backs; lightly thicker, less pointed, and more unicolored tails; and often darker colored bellies. Most representatives of the northern subspecies have whitish bellies. Animals found in the Suisun Bay region have tails that are longer than their head and body lengths. Most individuals of the southern subspecies have cinnamon-colored bellies and shorter tails than their head and body lengths. The cinnamon or rufous-colored venter of these southern forms gave rise to the name "red-bellied" harvest mouse, an interesting but inappropriate name for the species as a whole.

It is difficult to differentiate between salt marsh and western harvest mice in the field. Identifying characteristics include the general body color, color of the ventral hairs, thickness and shape of the tip of the tail, tail/body ratios, and behavior (Fisler 1965, Shellhammer 1981). Tail length and venter coloration show clinal variation throughout the range of the species. The only significant cranial difference between the two subspecies is the depth of the brain case (Fisler 1965).

Distribution: Salt marsh harvest mice evolved with the creation of San Francisco Bay some 8,000-25,000 years ago. According to Fisler (1965), these mice were found in most of the marshes throughout San Francisco Bay. The wetlands and marshes of the original Sacramento-San Joaquin Delta were probably too fresh to support mice, and hence, the Collinsville-Antioch area probably was, and still is, the eastern limit of their distribution. During the last 200 years, approximately 79% of the tidal marshes of San Francisco Bay have been filled, flooded, or converted to other types of vegetation (Jones & Stokes, Inc. et al. 1979). A large area has been converted to diked wetland, most of which is marginal or inappropriate habitat for harvest mice. Most of the remaining tidal marshes are fragmented strips situated along outboard dikes and along sloughs often separated from one another by considerable distances.

The western limit of the northern subspecies is the marshes bordering the mouth of Gallinas Creek on the upper Marin Peninsula. Narrow strips of marshes extend northward into and along the Petaluma River and connect to the large Petaluma Marsh. Lower Tubbs Island, further east along San Pablo Bay, is being restored to tidal action by the USFWS and will provide a sizable marsh in the future. Many of the marshes in the Napa Marsh are too narrow and steep to support salt marsh harvest mice, although mice are present along Napa Slough and Sonoma Creek, on Coon Island, and in the Fagan Marsh. The marsh along San Pablo Bay from Sonoma Creek to Mare Island is naturally expanding from sediment accretion and is one of the major refugia for this species in San Pablo Bay. It is the principal marsh within the San Pablo Bay National Wildlife Refuge.

Repeated trapping in the Southampton Bay Marsh failed to capture any harvest mice; the next populations east of Mare Island are in Suisun Marsh. This huge wetland is managed primarily as waterfowl habitat and, until recently, to enhance alkali bulrush (*Scirpus robustus*), once considered a preferred food for mallard (*Anas platyrhynchos*) and pintail (*A. acuta*). Salt marsh harvest mice in this wetland are present in low numbers in pickleweed (*Salicornia virginica*) areas that are scattered among the alkali bulrush. Moderate populations of mice occur in the diked marshes near Collinsville and in diked and tidal marshes along the Contra Costa County coast.

Habitat and Life History: Salt marsh harvest mice are critically dependent on dense cover and their preferred habitat is pickleweed (Fisler 1965; Wondolleck et al. 1976; Shellhammer 1977, 1981). Harvest mice are seldom found in cordgrass (*Spartina foliosa*) or alkali bulrush (Fisler 1965, Wondolleck et al. 1976, Shellhammer 1977, Harvey and Stanley Associates 1980, Shellhammer 1981, Shellhammer et al. 1982). In marshes with an upper zone of peripheral halophytes, mice use the vegetation to escape the higher tides and may even spend a considerable portion of their lives there. Fisler (1965) notes that mice also move into the adjoining grasslands during the highest winter tides.

Throughout much of the range of the salt marsh harvest mouse, subsidence and diking have eliminated the important peripheral halophyte zone. This is especially evident around south San Francisco Bay. Few harvest mice survive in such marshes, even though other marsh conditions may be optimal, because there is little or no high tide escape cover.

Studies have shown that the best type of pickleweed association for harvest mice has 100% ground cover, a cover depth of 30-50 cm at summer maximum, 60% or more of pickleweed cover, and complexity in the form of fat hen (*Atriplex patula*) and alkali heath (*Frankenia salina*) or other halophytes (USFWS et al. 1984).

The amount of salt grass (*Distichlis spicata*), brass buttons (*Cotula coronopifolia*), alkali bulrush, or other species (*Typha* sp., *Scirpus* sp.) should be low. These species may be present, but not in large continuous stands. Salt grass and brass buttons provide very poor habitat for harvest mice. They are low-growing, lack stratification, and provide poor cover. Fat hen provides good cover for mice during the summer but cannot be used year-round because it is an annual.

Salt marsh harvest mice are placid in comparison to western harvest mice or house mice. Their temperament correlates with their habitat. The much more active western harvest mice live in more open environments and use their quickness to escape predators (Fisler 1965). The less active salt marsh harvest mouse is so dependent on cover that roads or open areas as small as 10 m wide appear to act as barriers to movement (Shellhammer 1978). These behavioral differences are so great that they are useful in field identification (Fisler 1965, Shellhammer 1981).

Salt marsh harvest mice swim well, floating on the surface "like corks" (Fisler 1965). The western harvest mouse swims violently and poorly, and its fur becomes rapidly wetted. Salt marsh harvest mice do not burrow. The northern subspecies may build nests or cap over old bird nests (Fisler 1965), but the southern form often does not build a nest at all. Nests are often a loose ball of grasses on the surface of the ground and may be abandoned with the next high tide.

Salt marsh harvest mice are partly diurnal. Fisler (1965) suggests that the most placid and least nocturnal individuals live in the densest cover.

According to Fisler (1965), male harvest mice are reproductively active from April through September, although some males appear reproductively active year-long. Although females have a long breeding season that extends from as early as March to November, they apparently have a low reproductive potential. This may be due to the relatively small average litter, between 3.72 and 4.21 (Fisler 1965), and the fact that females do not have many litters per year. Fisler (1965) estimates that females of the northern subspecies may have only one litter per year.

Fisler (1965) notes that salt marsh harvest mice eat green vegetation in addition to seeds. They have longer intestines than the western harvest mouse, which is a seed eater. The northern subspecies of the salt marsh harvest mouse can drink seawater for long periods of time but prefers to drink freshwater. The southern subspecies is unable to drink seawater as its only drinking fluid but prefers moderately saline water (Fisler 1965). These preferences correlate with the habitats that these forms occupy. The northern subspecies typically lives in more brackish marshes where the range of salinities is wide, but the average is not very saline. The southern subspecies lives in marshes where the average salinity is relatively high and stable. The effect of salinity on the diet of these mice is only partially understood (Fisler 1963, Haines 1964, Coulombe 1970) but may be a critical factor in their management.

Little is known about the natural causes of mortality in this species. Snakes, owls, hawks, and various other potential predators inhabit most marshes, but their impact is not known.

Abundance: There are five principal reasons for the decline of the salt marsh harvest mouse: habitat loss, fragmentation of the remaining marshes, widespread loss of the high marsh zone as a result of backfilling, land subsidence, and vegetational change (USFWS et al. 1984).

The present status of the salt marsh harvest mouse appears to be a few thousand animals at the peak of their numbers each summer, distributed around San Francisco Bay marshes in small, disjunct populations, often in marginal vegetation and almost always in marshes without an upper edge of upland vegetation (USFWS et al. 1984).

Occurrence at the Pittsburg and Contra Costa Power Plants and the Montezuma Habitat Enhancement Site: Live trapping studies conducted in 1978 at the Pittsburg Power Plant property revealed the presence of salt marsh harvest mice (WESCO 1979). The draft revised California Clapper Rail/Salt Marsh Harvest Mouse Recovery Plan targets areas along Suisun Bay on the Pittsburg site as essential habitat.

Surveys conducted at the Montezuma Enhancement Site between October 1977 and August 1978 (Biosystems Analysis, Inc. 1980) resulted in detection of salt marsh harvest mouse. However, no salt marsh harvest mice have been detected since that time, including a 1994 survey that involved 75 trap nights. Salt marsh harvest mouse habitat has declined at the site in the past 20 years and only 9.78 acres of suitable habitat remained in 1996.

The 1984 California Clapper Rail/Salt Marsh Harvest Mouse Recovery Plan identified the Montezuma Enhancement Site as a "Priority 3" essential habitat area to be managed as a diked marsh. However, the draft revised plan no longer includes this area as essential habitat.

No sensitive terrestrial species are known to occur on the Contra Costa site.

APPENDIX B. PREVIOUS AQUATIC MONITORING PROGRAMS

Pacific Gas and Electric Company (PG&E) performed a variety of investigations at the Pittsburg and Contra Costa power plants to characterize fish losses resulting from circulating water system operations, and identify and implement measures to minimize these losses. Operation of a power plant's circulating water system has the potential for impacting aquatic organisms through entrainment, impingement, and exposure to elevated water temperatures within the thermal discharge plume. Estimated numbers of the sensitive species entrained and impinged at the power plants are summarized below based on results of monitoring performed in 1978/1979 [316 (b) evaluations] and in 1986-1992 (striped bass monitoring program). Although these monitoring programs focussed on striped bass, they provide additional information on entrainment and impingement of Delta smelt, longfin smelt, Sacramento splittail, chinook salmon, steelhead, and green sturgeon. The data are used in combination with monitoring data on circulating water system operations (circulating water pump operations) to estimate the numbers of each fish species entrained and impinged during the monitoring period.

PG&E conducted these studies to comply with National Pollution Discharge Elimination System permit provisions issued by the Regional Water Quality Control Boards for the operation and monitoring of a cooling water system at both power plants. These programs have been conducted cooperatively with the San Francisco Bay and Central Valley Regional Water Quality Control Board, the California Department of Fish and Game (CDFG), the U.S. Fish and Wildlife Service (USFWS), and the National Marine Fisheries Service (NMFS). To minimize impacts identified during these evaluations, significant modifications to equipment and operations have been incorporated at the Pittsburg and Contra Costa power plants. These modifications are discussed below.

B-1.0 ENTRAINMENT

Entrainment is the hydraulic capture and subsequent passage of organisms through the cooling water system. The organisms involved are small (typically, less than 20 mm long), unable to avoid the screens, and capable of passing through the 3/8-inch mesh of the intake screens and include eggs, larvae, and early juvenile stages of various fish species. As these entrained organisms pass through the cooling water system, they can be exposed to several types of stresses. These include mechanical, pressure, shear, thermal, and chemical stresses. The potential impact of entrainment is a function of the number of organisms that do not survive passage through the cooling water system.

B-1.1 Entrainment Investigations Prior to 1982

Entrainment studies were conducted at the Pittsburg and Contra Costa power plants in 1978/1979 as part of the 316(b) demonstration program (PG&E 1981a, b). The studies provided detailed information on species composition, numbers of various fish and macroinvertebrates entrained at the cooling water intakes, the size distribution of organisms, the diel distribution, and seasonal patterns. In addition, detailed studies were also conducted to determine the survival of organisms, primarily larval striped bass and mysid shrimp, entrained through the cooling water system and to separate the influence of mechanical and thermal stress as factors influencing entrainment survival. The entrainment studies were conducted during a 16-month period in 1978 and 1979 and provided the baseline information for subsequent entrainment monitoring. Entrainment monitoring was conducted at a sampling frequency of one 24-hour sampling period per week. As a consequence of the inability to taxonomically differentiate between larval longfin smelt and delta smelt, results of entrainment monitoring performed during these studies were combined and reported in most cases only as smelt (*Osmeridae*).

Based on results of entrainment monitoring, estimates of the annual numbers of larval fish and eggs entrained at the two power plants were calculated based on actual circulating water system operations. However, these entrainment estimates do not consider survival of entrained organisms returned to the receiving waters. The estimated numbers of entrained larval Delta smelt, longfin smelt, Osmeridae, Sacramento splittail, chinook salmon, steelhead, and green sturgeon are summarized in Table B-1.

Table B-1. Total Number of Fish Collected and Estimated Annual Entrainment at the Pittsburg and Contra Costa Power Plants (1978/1979)

	Delta Smelt	Longfin Smelt	Osmeridae	Sacramento Splittail	Chinook Salmon	Steelhead	Green Sturgeon	totals
PITTSBURG POWER PLANT								
Number of fish collected[1]	46	13	2,278	16	1	0	0	
Estimated annual entrainment[2]	455,413 ±184,516	190,229 ±198,009	64,784,071 ±29,475,225	155,289 ±60,064	23,598 ±35,468	0	0	65,605,600
CONTRA COSTA POWER PLANT								
Number of fish collected[1]	4	0	1,518	34	2	0	0	
Estimated annual entrainment[2]	21,887 ±23,881	0	20,543,854 ±5,601,594	189,659 ±118,820	10,318 ±18,820	0	0	6,608,651 (6 & 7 only)

[1] Represents total number of fish collected during entire study period.
[2] Estimated annual entrainment based on design flow and includes 95% confidence interval.

Based on examination of the length frequency data from these entrainment samples, it was estimated that 94% of the entrained smelt at the Pittsburg Power Plant ranged from 5 to 7 mm in length. The significance of the 1978/1979 smelt entrainment loss estimate (which does not consider entrainment survival) on the resulting recruitment of adult smelt may be substantially reduced by the small size of entrained larvae and high natural mortality rates. Most of the larvae were collected in the January-February period, which is somewhat early for Delta smelt. This, coupled with the high ratio of longfin smelt to Delta smelt found in the impingement results at the Pittsburg Power Plant suggest that most of the entrained larvae may have been longfin smelt.

B-1.2 Entrainment Investigations from 1986 through 1992

As part of PG&E's program to reduce striped bass entrainment losses, striped bass entrainment monitoring has been performed at both power plants since 1986. Each year, entrainment monitoring commenced May 1 and typically continued to mid-July. The number of entrainment samples, total cooling water volume sampled, and the numbers of *Osmeridae* (both Delta and longfin smelt combined), Delta smelt, longfin smelt, Sacramento splittail, chinook salmon, steelhead, and green sturgeon collected in these entrainment samples are summarized in Table B-2. During the early period of this entrainment monitoring program (1986-1989), larval Delta smelt and longfin smelt could not be taxonomically differentiated with confidence and, therefore, results of these collections have been combined and recorded as *Osmeridae*. Beginning in 1990, taxonomic identification of larval delta smelt and longfin smelt improved, and the two species have been recorded separately.

Table B-2. Total Number of Fish Collected and Estimated Annual Entrainment at the Pittsburg and Contra Costa Power Plants (1986-1992) [1]

	Delta Smelt	Longfin Smelt	Osmeridae	Sacramento Splittail	Chinook Salmon	Steelhead	Green Sturgeon
PITTSBURG POWER PLANT							
Number of fish collected[2]	4	18	126	26	0	0	0
Estimated annual entrainment[3]	51,698 ±50,644	232,641 ±133,854	1,628,489 ±1,388,542	336,037 ±147,334	0	0	0
CONTRA COSTA POWER PLANT							
Number of fish collected[2]	4	6	128	8	0	0	0
Estimated annual entrainment[3]	47,453 ±46,485	71,179 ±56,917	1,518,480 ±1,712,930	94,905 ±65,705	0	0	0

2,248,865

(6+7 only)

[1] Data collected from May 1 - July 15.
[2] Represents total number of fish collected during the 7-year study period.
[3] Estimated annual entrainment based on densities over the May-July sampling period and on design flow for 12 months, and includes 95% confidence interval.

these #s don't match table 3-16 is it because these are annual estimates & table 3-16 is May-July only?

275

To estimate the total numbers of each species entrained at the Contra Costa and Pittsburg power plants during the period of entrainment monitoring, results of individual collections reported on Table 3-7 have been converted to a density estimate (number /m^3) and combined with data on cooling water flow (m^3 during each week) to estimate the total numbers of organisms entrained.

Entrainment survival data for larval striped bass (PG&E 1981a, b) and other larval fish generally indicate a strong relationship between temperature and survival. However, because entrainment survival data are not available for Delta smelt, longfin smelt, Sacramento splittail, chinook salmon, steelhead, and green sturgeon, 100% entrainment loss must be assumed. The significance of estimates of entrainment loss of fish larvae on populations of Delta smelt, longfin smelt, Sacramento splittail, chinook salmon, steelhead, and green sturgeon inhabiting the Bay/Delta system is difficult to assess.

Results of entrainment monitoring have shown that the numbers of Delta smelt, longfin smelt, and Sacramento splittail lost after modifications to plant equipment and operations have been generally reduced when compared to pre-modification data.

B-2.0 IMPINGEMENT

Impingement occurs when an organism is held against the intake screens used to remove debris from the cooling water. Fish susceptible to impingement are typically large juveniles and adults (typically greater than 38 mm long) that have died from other causes or are in a weakened condition. The survival of impinged fish depends on the species, lifestage, and size of the organism. Other factors influencing impingement survival include the duration of impingement and the techniques of handling impinged organisms and returning them to the water body, as well as seasonal water body characteristics, such as salinity, water temperature, etc.

B-2.1 Impingement Investigations prior to 1982

The first investigations were performed at the Contra Costa Power Plant Units 1-5 intake during the early 1950's (Kerr 1953). The objective of these early studies was to modify the Units 1-5 intake system to minimize the numbers of fish impinged. As a result of these early investigations, an effective fish pump removal system designed to remove fish from the area in front of the screens was installed at the Units 1-5 intake. The fish pump was effective in substantially reducing the numbers of fish impinged while maintaining high survival rates for those fish removed from the intake and returned to the water body (Kerr 1953, PG&E 1981a). In addition, based on results of the early investigations, Kerr (1953) developed design criteria for cooling water intake structures to minimize and avoid fish impingement. The recommended design criteria (e.g., intake approach velocities, configuration of the intake structure including lateral fish escape routes and intake screens located parallel to the shoreline, and avoidance of recessed intake configurations where fish may become entrapped) were used in the design of the Contra Costa Units 6 and 7 and Pittsburg Units 1-7 cooling water intake structures and have been recognized nationally as the recommended design for power plant once-through cooling water systems (EPA 1977).

Impingement survival studies were also conducted for various fish and macroinvertebrate species to determine the effects of alternative intake screen operational modes (frequency of intake screen rotation and duration of impingement) and to document the effectiveness and survival of fish removed from the Contra Costa Units 1-5 intake through the fish pump return system.

The estimated numbers of Delta smelt, longfin smelt, Sacramento splittail, chinook salmon, steelhead, and green sturgeon impinged at each cooling water intake structure at both power plants were also estimated based on actual cooling water system operations. Results of annual impingement estimates are summarized in Table B-3.

Table B-3. Total Number of Fish Collected and Estimated Annual Impingement at PG&E's Delta Power Plants (1978/1979)

	Delta Smelt	Longfin Smelt	Osmeridae	Sacramento Splittail	Chinook Salmon	Steelhead	Green Sturgeon
PITTSBURG POWER PLANT							
Number of fish collected[1]	1,490	13,466	3	1,517	141	0	0
Estimated annual impingement[2]	14,082 ± 6,454	137,261 ± 55,576	25 ±29	8,732 ± 4,596	808 ±331	0	0
CONTRA COSTA POWER PLANT							
Number of fish collected[1]	1,747	1,275	0	1,792	176	0	1
Estimated annual impingement[2]	8,253 ±1,595	19,475 ±11,758	0	12,455 ±3,422	763 ±316	0	0

[1] Represents total number of fish collected during entire study period.
[2] Estimated annual impingement based on design flow and includes 95% confidence interval.

Even though individual lengths of the chinook salmon collected during the 316(b) impingement studies for the Pittsburg Power Plant are not available, monthly length ranges were recorded in Appendix E of the 316(b) Demonstration (Ecological Analysts, Inc. 1981a). The monthly totals and length ranges for the fish collected during the 1978-79 impingement sampling, and the length categories for the different run types are shown in Table B-4. The "X" values in the columns indicate the groups of fish that fall into each run category. Because each fish could fall into one or more run categories, the sum of the maximum number by run is greater than the actual number collected.

Table B-4. Total Number and Length Ranges of Chinook Salmon Collected during Impingement Sampling at the Pittsburg Power Plant (March 1978 - March 1979) and Salmon Run Categories based on Length and Month of Capture

MONTH & YEAR OF CAPTURE	Number of fish collected	Length range of fish collected (mm)	Chinook salmon run categories (mm) (from CDFG 1991 unpublished data, Frank Fisher)					
			Winter-run		Spring-run		Fall/late fall-run[1]	
MAR 78	0		81-199		60-99		0-73, 164-270	
APR 78	14	48-85	99-243		73-120	X[2]	0-89, 201-270	X
MAY 78	3	59-72	121-270		89-147		0-109, 244-270	X
JUN 78	8	60-88	148-270		110-179		0-133	X
JUL 78	3	57-80	0-40, 181-270		133-220		33-163	X
AUG 78	0		0-50, 221-270		164-269		41-199	
SEP 78	0		0-60		201-270		50-243	
OCT 78	0		0-74		0-37,244-270		61-270	
NOV 78	5	73-108	37-90	X	0-45		74-270	X
DEC 78	9	120-181	45-110		33-55		0-33, 91-201	X
JAN 79	10	43-258	55-135	X	41-67	X	0-50, 111-246	X
FEB 79	16	32-83	67-163	X	50-80	X	0-59, 136-270	X
MAR 79	20	42-128	81-199	X	60-99	X	0-73, 164-270	X
APR 79	12	57-106	99-243	X	73-120	X	0-89, 201-270	X
MAY 79	18	60-103	121-270		89-147	X	0-109, 244-270	X
JUN 79	13	71-90	148-270		110-179		0-133	X
JUL 79	10	60-91	181-270, 0-40		133-220		33-163	X
AUG 79	0		221-270, 0-50		164-269		41-199	
SEP 79	0		0-60		201-270		50-243	
OCT 79	0		0-74		0-37, 244-270		61-270	
NOV 79	0		37-90		0-45		74-270	
			Maximum Number and Percentage of Total Collected[3]					
			Winter-run		Spring-run		Fall/late fall-run	
			#	%	#	%	#	%
TOTAL	141		57	40	82	58	136	96

[1] Late fall and fall-run categories were combined to create this category.
[2] Individual lengths of salmon collected during the 1978-79 studies were not retrievable. Using the length ranges of the salmon collected , the "X" values in the columns indicate the groups of fish that fall into the various run categories based on length and date of capture. The table used to group these fish was developed from analyses conducted by Frank Fisher of CDFG (1991 unpublished data). This table was attached to the 1995 CDFG Memorandum of Understanding (MOU) for PG&E's fisheries sampling at the Pittsburg and Contra Costa power plants.
[3] The maximum number of fish and % of the total number from the 1978-79 studies that could fall into the various run types are shown at the bottom of the table.

Even though individual lengths of the chinook salmon collected during the 316(b) impingement studies for the Contra Costa Power Plant are not available, monthly length ranges were recorded in Appendix E of the "Cooling Water Intake Structure 316(b) Demonstration" (Ecological Analysts, Inc. 1981b). The monthly totals and length ranges for the fish collected during the 1978-79 impingement sampling, and the length categories for the different run types are shown in Table B-5 for Units 1-7 and Table B-6 for Units 6&7. The "X" values in the columns indicate the groups of fish that fall into each run category. Because each fish could fall into one or more run categories, the sum of the maximum number by run is greater than the actual number collected.

Table B-5. Total Number and Length Ranges of Chinook Salmon Collected during Impingement Sampling for Units 1-7 at the Contra Costa Power Plant (April 1978 - January 1980) and Salmon Run Categories based on Length and Month of Capture

MONTH & YEAR OF CAPTURE	Number of fish collected	Length range of fish collected (mm)	Chinook salmon run categories (mm) (from CDFG 1991 unpublished data, Frank Fisher)					
			Winter-run		Spring-run		Fall/late fall-run[1]	
APR 78	15	55-83	99-243		73-120	X[2]	0-89	X
MAY 78	12	67-88	121-270		89-147		0-109	X
JUN 78	41	58-102	148-270		110-179		0-133	X
JUL 78			0-40		133-220		33-163	
AUG 78			0-50		164-269		41-199	
SEP 78			0-60		201-270		50-243	
OCT 78			0-74		0-37, 244-270		61-270	
NOV 78	2	106-159	37-90		0-45		74-270	X
DEC 78	5	101-163	45-110	X	33-55		0-40, 91-270	X
JAN 79	1	120	55-135	X	41-67		0-50, 111-270	X
FEB 79	3	40-108	67-163	X	50-80	X	0-59, 136-270	X
MAR 79	5	58-94	81-199	X	60-99	X	0-73, 164-270	X
APR 79	6	70-86	99-243		73-120	X	0-89, 201-270	X
MAY 79	16	72-92	121-270		89-147	X	0-109, 244-270	X
JUN 79	25	65-110	148-270		110-179	X	0-133	X
JUL 79	12	69-100	181-270, 0-40		133-220		33-163	X
AUG 79			221-270,0-50		164-269		41-199	
SEP 79	1	82	0-60		201-270		50-243	X
OCT 79	4	141-162	0-74		244-270 0-37		61-270	X
NOV79	25	95-187	37-90		0-45		74-270	X
DEC 79	2	111-123	45-110		33-55		0-40, 91-270	X
JAN 80	1	128	55-135	X	41-67		0-50, 111-270	X
			Maximum Number and Percentage of Total Collected[3]					
			Winter-run		Spring-run		Fall/late fall-run	
			#	%	#	%	#	%
TOTAL	176		12	7	63	36	174	98

[1] Late fall and fall-run categories were combined to create this classification.

[2] Individual lengths of salmon collected during the 1978-79 studies were not retrievable. Using the length ranges of the salmon collected, the "X" values in the columns indicate the groups of fish that fall into the various run categories based on length and date of capture. The table used to group these fish was developed from analyses conducted by Frank Fisher of CDFG (1991 unpublished data). This table was attached to the 1995 CDFG Memorandum of Understanding (MOU) for PG&E's fisheries sampling at the Pittsburg and Contra Costa power plants.

[3] The maximum number of fish and percentage of the total from the 1978-79 studies that could fall into the various run types are shown at the bottom of the table.

Table B-6. Total Number and Length Ranges of Chinook Salmon Collected during Impingement Sampling for Units 6&7 at the Contra Costa Power Plant (April 1978 - January 1980) and Salmon Run Categories based on Length and Month of Capture

MONTH & YEAR OF CAPTURE	Number of fish collected	Length range of fish collected (mm)	Chinook salmon run categories (mm) (from CDFG 1991 unpublished data, Frank Fisher)					
			Winter-run		Spring-run		Fall/late fall-run[1]	
APR 78	13	55-83	99-243		73-120	X[2]	0-89	X
MAY 78	10	67-83	121-270		89-147		0-109	X
JUN 78	10	64-98	148-270		110-179		0-133	X
JUL 78			0-40		133-220		33-163	
AUG78			0-50		164-269		41-199	
SEP 78			0-60		201-270		50-243	
OCT 78			0-74		0-37, 244-270		61-270	
NOV 78			37-90		0-45		74-270	
DEC 78			45-110		33-55		0-40, 91-270	
JAN 79			55-135		41-67		0-50, 111-270	
FEB 79	3	40-108	67-163	X	50-80	X	0-59, 136-270	X
MAR 79	1	58	81-199		60-99		0-73, 164-270	X
APR 79	3	70-75	99-243		73-120	X	0-89, 201-270	X
MAY 79	14	72-92	121-270		89-147	X	0-109, 244-270	X
JUN 79	14	65-110	148-270		110-179	X	0-133	X
JUL 79	9	69-100	181-270, 0-40		133-220		33-163	X
AUG 79			221-270, 0-50		164-269		41-199	
SEP 79			0-60		201-270		50-243	
OCT 79			0-74		244-270, 0-37		61-270	
NOV 79	3	119-151	37-90		0-45		74-270	X
DEC 79			45-110		33-55		0-40, 91-270	
JAN 80			55-135		41-67		0-50, 91-270	
			Maximum Number and Percentage of Total Collected[3]					
			Winter-run		Spring-run		Fall/late fall-run	
			#	%	#	%	#	%
TOTAL	80		2	3	42	53	79	99

[1] Late fall and fall-run categories were combined to create this classification.
[2] Individual lengths of salmon collected during the 1978-1979 studies were not retrievable. Using the length ranges of the salmon collected, the "X" values in the columns indicte the groups of fish that fall into the various run categories based on length and date of capture. The table used to group these fish was developed from analyses conducted by Frank Fisher of CDFG (1991 unpublished data). This table was attached to the 1995 CDFG Memorandum of Understanding (MOU) for PG&E's fisheries sampling at the Pittsburg and Contra Costa Power Plants.
[3] The maximum number of fish and percentage of the total from the 1978-1979 studies that could fall into the various run types are shown at the bottom of the table.

B-2.2 Impingement Investigations from 1987 through 1990

Impingement monitoring was performed at cooling water intakes for both power plants over 3 years from 1987 through 1990. In general, the impingement sampling was done once a month from August through February. The number of *Osmeridae*, Delta smelt, longfin smelt, Sacramento splittail, chinook salmon, steelhead, and green sturgeon collected in impingement samples during each of these periods is summarized in Table B-7. Unlike entrainment monitoring where a relatively small volume of cooling water is sampled, impingement samples reflect all fish impinged during the period of sampling. No green sturgeon were collected during the 3 years at both power plants, and only three chinook salmon were collected during the same period. The numbers of Delta smelt (26) and Sacramento splittail (23) collected during these impingement samples were also relatively low. The numbers of longfin smelt collected, particularly during the 1987/1988 surveys were substantially higher at the Pittsburg Power Plant (359) than numbers collected at the Contra Cost Power Plant (7).

Table B-7. Total Number of Fish Collected and Estimated Annual Impingement at the Pittsburg and Contra Costa Power Plants (1987-1990) [1]

	Delta Smelt	Longfin Smelt	Osmeridae	Sacramento Splittail	Chinook Salmon	Steelhead	Green Sturgeon
PITTSBURG POWER PLANT							
Number of fish collected[2]	8	359	0	6	3	0	0
Estimated annual impingement[3]	283 ±1,003	12,677 ±46,052	0	212 ±513	106 ±517	0	0
CONTRA COSTA POWER PLANT							
Number of fish collected[2]	18	7	0	17	0	0	0
Estimated annual impingement[3]	942 ±2,125	366 ±1,768	0	889 ±2,136	0	0	0

[1] Data collected from August 1 - February 28.
[2] Represents total number of fish collected during study period.
[3] Estimated annual impingement based on densities established in the August-February sampling and on design flow for 12 months, and includes 95% confidence interval.

Results of impingement monitoring have been used (based on actual cooling water volumes) to estimate the total numbers of each species impinged during the period when monitoring data are available. Because of their sensitivity to handling and stress, impingement loss estimates for Delta smelt, longfin smelt, Sacramento splittail, and chinook salmon have been made based on the assumption of 100% impingement mortality.

Results of impingement monitoring have shown that the numbers of Delta smelt, longfin smelt, Sacramento splittail, chinook salmon, steelhead, and green sturgeon lost after modifications to plant equipment and operations have been low.

B-3.0 POWER PLANT MODIFICATIONS TO REDUCE ENTRAINMENT AND IMPINGEMENT LOSSES

As a result of the relatively large entrainment and impingement losses documented in the 1978/1979 studies at both power plants, PG&E initiated an assessment of design and operational modifications to the plants to reduce fishery losses. The evaluation of alternative technologies (Tera 1982) included consideration of 43 structural and operational modifications designed to reduce the numbers of fish entrained and impinged through cooling water volume reduction and improving the survival of organisms that are entrained or impinged. The resulting best technology available (BTA) program incorporated a variety of structural and operational changes to cooling water system operations. These included:

- Variable speed circulating water pump controls for Contra Costa Units 6 and 7 and Pittsburg Units 5 and 6.
- Seasonal program of preferential operation of Pittsburg Unit 7, which is equipped with mechanical draft cooling towers.
- Operation and dispatch of units during spring (typically May through mid-July) to reduce, to the extent possible, unit operations, cooling water flows, and the frequency of discharge temperatures exceeding 86°F.
- Entrainment monitoring to determine the appropriate period for implementing operational changes based on seasonal patterns in the densities of larval striped bass.
- Entrainment monitoring to dispatch units based on the geographic distribution of larval striped bass and in a method for evaluating the effectiveness of various actions in reducing larval striped bass losses.

In 1985, PG&E re-examined the performance of measures implemented at the two power plants, and additional modifications were recommended to further reduce fisheries losses (TENERA 1985). Based on results of this re-examination, PG&E performed additional modifications to the cooling water systems at the Contra Costa and Pittsburg power plants including the following:

- Installation of variable-speed circulating water pump controls at Contra Costa Units 4 and 5 and Pittsburg Units 1-4.
- Operation of mechanical crossovers to reduce cooling water volumes at Contra Costa Units 1-3.
- Installation of a hydrogen cooler at Contra Costa Units 6 and 7.

In 1991, PG&E again conducted a re-examination of alternative technologies to reduce fisheries losses at the two power plants. The re-examination was performed to determine if new or improved technologies had been developed since completing the 1985 review (TENERA 1985). Results of the 1991 re-examination (PG&E 1992) were reviewed by the CDFG and the USFWS and were submitted to the San Francisco and Central Valley Regional Water Quality Control Boards. It was concluded that the design and operational changes implemented at the Contra

Costa and Pittsburg power plants have been effective in reducing fisheries losses, and no additional design modifications were identified or required.

B-4.0 THERMAL EFFECTS

Potential effects associated with exposure to power plant thermal discharge plumes include behavioral avoidance of potential habitat, behavioral attraction, increased susceptibility to predation, sublethal stresses resulting in reduced health and fitness, and potential acute mortality as a consequence of exposure to elevated temperatures. The response of a fish species to the thermal discharge plume varies depending on the thermal tolerance and physiology of the species, its lifestage, acclimation temperature, the duration of exposure, the difference in temperatures between the acclimation temperature and the exposure temperature (delta-T), and the absolute temperature to which the organisms are exposed. Factors such as the geographic distribution of the thermal plume, the vertical distribution of the plume within the water column, mixing characteristics, the thermal dissipation (temperature decay), and the configuration and characteristics of discharge are important factors affecting the potential biological significance of exposure to the discharge.

Pittsburg and Contra Costa power plant investigations to address thermal impacts of the discharges have not identified any adverse effects associated with exposure of fish to temperatures occurring within the thermal discharge plumes. These studies include 316 (a) studies that were completed in the mid-1970s and the recent 1991/1992 Thermal Effects Assessment (PG&E 1992). Results of field data collection efforts, particularly the 1991/1992 evaluation, have been characterized by low, or highly variable abundances of many target species, including longfin and Delta smelt near the power plants. The populations of many of the native fishes have been low in areas both within and outside of the discharge plume, which is consistent with the documented decline in abundance of these native species through the 1980s. Even though Sacramento splittail have also decreased throughout the estuary, splittail have been commonly collected within both areas exposed to the discharge plumes and at reference locations, demonstrating no apparent avoidance of the discharge areas. The discharge areas associated with both power plants support diverse fisheries communities and, with the exception of the area within the Contra Costa Units 6 and 7 discharge canal, no evidence was found that suggested either behavioral avoidance or adverse effects as a direct consequence of exposure to the discharge from either power plant.

B-4.1 Thermal Plume Evaluations prior to 1982

PG&E conducted extensive field studies during 1971/1972 (PG&E 1973a, b) to evaluate potential effects associated with the discharges from the Pittsburg and Contra Costa power plants on aquatic organisms inhabiting the receiving waters. These investigations included discharge plume monitoring and biological surveys. No significant adverse effects were identified during these investigations.

During the mid-1970s PG&E again conducted evaluations of the potential adverse effects associated with discharges from the Pittsburg and Contra Costa power plants (TetraTech 1976a, b). These studies provided additional information on the characteristics of the power plant discharge plumes. Results of discharge monitoring were used in combination with biological survey data to develop a model to evaluate the potential adverse effects of the power plant discharge plumes on striped bass and other aquatic resources. Results of these investigations did not identify significant adverse environmental effects on striped bass and other aquatic resources as a consequence of exposure to the discharge plumes. Based on results of these investigations, the Central Valley and San Francisco Bay Regional Water Quality Control Boards authorized exemptions for the two power plants from State Thermal Plan Standards.

B-4.2 Thermal Plume Investigations in 1991 and 1992

In 1990, the San Francisco and Central Valley Regional Water Quality Control Boards requested that PG&E re-examine potential effects of discharges from the Contra Costa and Pittsburg power plants on aquatic resources inhabiting the lower San Joaquin River and Suisun Bay. In response to the need for additional information, PG&E performed a study to assess the effects of water temperature on aquatic organisms inhabiting receiving waters for the thermal discharges of both power plants. The 1-year investigation was conducted from July 1991 through June 1992. The study included 1) an intensive water temperature monitoring program at the power plant cooling water discharges and receiving waters, and 2) monthly fisheries surveys at locations within the discharge plumes and at reference locations outside of the area of discharge plume exposure. During routine monthly fisheries surveys conducted as part of this investigation, information was collected on the presence of other fish species including Delta smelt, longfin smelt, Sacramento splittail, and chinook salmon in the receiving waters of both power plants.

Fisheries surveys were conducted monthly within the thermal discharges of both power plants and at reference sites. A variety of active and passive sampling techniques was used. The primary objectives of the monthly fisheries surveys were to describe the fisheries community inhabiting the discharge areas and to compare those discharge communities to populations located away from the discharge sites (reference locations). The second objective of the study was to document behavioral responses such as attraction, avoidance, and migration blockage created by the thermal component of the discharges. Measures to evaluate differences between discharge and reference populations included species abundance, species composition/diversity, size distribution, and fish condition. The health of fish within the discharge was compared to reference specimens by examining each individual for external parasites, disease, and deformities.

Active sampling gear used in this survey included bottom trawls, surface trawls, beach seines, and ichthyoplankton nets. Passive gears included gill nets and fyke nets. Electrofishing was also used to supplement standard monthly collection efforts. Sampling at Pittsburg Power Plant included three bottom trawl sampling stations, five surface trawl sampling stations, four gill net stations, four fyke net stations, two beach seine stations, two plankton stations, and five electrofishing stations. Sampling at Contra Costa Power Plant included four bottom trawl stations, four surface trawl stations, five gill net stations, four fyke net stations, two beach seine stations, two plankton stations, and four electrofishing stations. During each day's sampling effort, fish were collected during ebb and flood tidal conditions. Supplemental collections were also performed at night to assess potential diel variability.

A total of 1,674 fish representing 28 species and 16 families were collected in the vicinity of Pittsburg Power Plant during standard monthly collections between July 1991 and June 1992. A total of 3,769 fish representing 33 species and 16 families were collected during standard monthly fisheries surveys conducted in the vicinity of the Contra Costa Power Plant.

B-4.2.1 Delta Smelt. Delta smelt were collected in low numbers at the Contra Costa (25 fish) and the Pittsburg (21 fish) discharge and reference sites. The smelt were collected primarily in surface trawls, but they were also present in bottom trawls, fyke nets, and beach seines. At Contra Costa, the smelt were found between November and March and from July through August; at Pittsburg, the smelt were found between November and March and from July through September. In the plankton tows, Delta smelt were only collected in April surface tows, with larval delta smelt being collected at the Contra Costa discharge and reference sites and at the Pittsburg reference site.

B-4.2.2 Longfin Smelt. Longfin smelt were collected in low numbers at the Contra Costa sites (2 fish) and at the Pittsburg sites (7 fish). No longfin were collected at discharge sampling locations for either facility. However, longfin smelt were collected in bottom and surface trawls at the Contra Costa and Pittsburg sites. Longfin smelt were found at Contra Costa only in December and at Pittsburg in November (1 fish), December (4 fish), February (1 fish), and April (1 fish). Larval longfin smelt were present in plankton collections between December and March at Contra Costa and in November and March at Pittsburg. Larval longfin smelt were present in surface and bottom plankton samples from the Contra Costa discharge and reference sites during both ebb and flood tides. Larval longfin smelt were also collected from the Pittsburg discharge and reference sites (surface samples) during ebb and flood tides.

B-4.2.3 Sacramento Splittail. Sacramento splittail were collected at discharge and reference locations at both power plants. Splittail were present during each month at both facilities, representing 4% (147 fish) of the fish collected at the Contra Costa sites and 12% (193 fish) at the Pittsburg sites. Juvenile and adult Sacramento splittail were collected, and all the specimens were generally in good condition, showing few signs of distress. Splittail were caught primarily in beach seines and bottom trawls, but were also present in surface trawls, fyke nets, gill nets, and during electrofishing. No larval splittail were collected in plankton surveys at either power plant.

B-4.2.4 Chinook Salmon. Chinook salmon were collected at the discharge and reference locations at both power plants. Most of the chinook salmon were smolts collected in February, March, and April. Using length categories provided in PG&E's 1995 MOU with the CDFG, smolts collected during the surveys were divided into the following groups: fall/late fall-run - 84% (145 fish), spring-run - 14% (25 fish), and winter-run - 2% (3 fish). Chinook smolts were caught primarily in the surface trawls and by electrofishing. A few adult fish were caught in gill nets, with 6 adults at Pittsburg and 1 adult at Contra Costa. The adults were caught in August, September, and October.

B-4.2.5 Green Sturgeon. A single green sturgeon was collected during the 1-year survey. This specimen was a subadult at 382 mm in length and was collected at one of the Contra Costa reference stations.

Data are not available from either laboratory or field investigations for use in predicting the behavioral response of Delta smelt, longfin smelt, or Sacramento splittail to various elevated water temperatures occurring within the Contra Costa and Pittsburg power plant discharges. Delta smelt and Sacramento splittail were collected in areas within the influence of the power plant discharges and at reference locations; however, the numbers of fish collected were insufficient to effectively determine behavioral avoidance or attraction patterns for these species. Longfin smelt were collected in fewer numbers than either Delta smelt or splittail. Additional information on the actual numbers of each taxa collected, sampling locations, and collection methods has been documented in PG&E (1992).

Results of the 1991/1992 Thermal Effects Assessment showed that the discharge plume from the Contra Costa Power Plant had a surface area (2°F isotherm) ranging from approximately 5.4 to 45.5 acres. The surface area of the discharge plume at the Pittsburg Power Plant ranged from approximately 7.8 to 90.5 acres. The discharge plumes from both power plants remained close to the shoreline, and the direction and extent of the discharge plume were influenced primarily by tides. Discharge plumes from both power plants were located predominantly in the upper portion of the water column in a thin lens near the water surface.

Results of the fisheries investigations completed to date have demonstrated that the receiving waters for both power plants support diverse fish communities. Survey results provided no evidence of direct mortality to either juvenile or adult fish as a consequence of exposure to the discharge plume from either power plant. Fish were collected in good condition in the vicinity of the Pittsburg and Contra Costa power plants. Delta smelt and Sacramento splittail were collected at the Pittsburg and Contra Costa discharge and reference sites, and a comparison of the results did not show a pattern of attraction or avoidance. However, the numbers of fish collected were too low to allow meaningful statistical analysis. The areal extent of the discharge plumes, the rapid decline in water temperatures due to thermal dissipation and turbulent mixing, and strong tidal currents help to mix the thermal component of the discharge with the ambient receiving waters. Species that may be exposed to water temperatures outside of their preferred range are not trapped by the discharge plume; the fish can easily avoid areas that are too warm by moving offshore or by dropping down in the water column. Based on results of extensive thermal plume monitoring and biological studies, it was concluded that, other than the area within the Contra Costa Units 6 and 7 discharge canal, avoidance or exclusion from available habitat, adverse effects on health and condition, and other potentially adverse effects on various fish species, including the sensitive species addressed in this plan, inhabiting the receiving waters are not anticipated.

In reviewing results of the 1991/1992 Thermal Effects Assessment, the CDFG, USFWS, NMFS, and the Central Valley and San Francisco Bay Regional Water Quality Control Boards concluded that there was no evidence of adverse effects from exposure of local fish populations (those of the lower San Joaquin River and Suisun Bay) to discharges from the Pittsburg and Contra Costa power plants. No additional monitoring or management actions were required based on results of the Thermal Effects Assessment program.

B-4.3 Entrainment Survival

The previous discussion on thermal effects addresses the impact of heated discharge water on fish populations using the receiving waters, and does not address the relationship between through-plant loss of entrained fish and exposure to elevated temperatures within the cooling water system. This question is addressed in the section on entrainment impacts.

Studies performed on larval striped bass, mysid shrimp, and other organisms (PG&E 1981a, b) have shown that entrainment survival is relatively high when cooling water discharge temperatures are less than 86°F. A substantial reduction in the frequency of discharge temperatures exceeding 86°F at the two power plants during the Striped Bass Entrainment Monitoring Program has contributed to a substantial increase in the survival of striped bass and other species of larval fish and macroinvertebrates. However, no species-specific data is available on the relationship between entrainment survival and discharge temperature for the species addressed in this plan, therefore, for the purposes of this plan it is assumed that no entrained fish survive.

APPENDIX C. RESULTS OF FLORISTIC SURVEYS OF MONTEZUMA ENHANCEMENT SITE

FAMILY	SPECIES	COMMON NAME	OBSERVED 1973-74 [2]	OBSERVED 1977-78 [3]
Alismataceae	*Alisma plantago-aquatica*	Broad-leaf Water-Plantain		X
Anacardiaceae	*Schinus molle* [4]	Peruvian Pepper Tree	X	X
	Toxicodenron diversilobum	Western Poison Oak	X	X
Apiaceae	*Conium maculatum*	Poison Hemlock		X
	Foeniculum vulgare	Fennel	X	X
	Hydrocotlye verticillata	Whorled Penny-wort	X	
Apocynaceae	*Apocynum cannabinum*	Clasping-leaf Dogbane	X	X
Asclepiadaceae	*Asclepias fascicularis*	Narrow-leaf Milkweed		X
	Asclepias eriocarpa	Indian Milkweed	X	
Asteraceae	*Achillea millefolium*	Common Yarrow		X
	Ambrosia psilostachya	Naked-spike Ragweed	X	X
	Anthemis cotula	Mayweed	X	X
	Artemisia douglasiana	Douglas' Wormwood		X
	Aster lentus	Suisun Aster		X
	Aster subulatus var. *ligulatus*	Slim Aster		X
	Baccharis douglasii	Douglas' False-willow		X
	Baccharis pilularis	Coyote Bush	X	X
	Baccharis salicifolia	Mulefat	X	X
	Centaurea solstitialis	Yellow Star-thistle	X	X
	Chamomilla suaveolens	Pineapple weed	X	
	Cirsium vulgare	Bull Thistle	X	X
	Conyza bonariensis	South American Conyza		X
	Cotula coronopifolia	Brass-buttons		X
	Euthamia occidentalis	Western Fragrant-golden-rod		X
	Gnaphalium stramineum	Cotton-batting Cudweed	X	X
	Gnaphalium luteo-album	Weedy Cudweed		X
	Grindelia camporum	Great Valley Gumweed		X
	Helenium bigelovii	Bigelow's Sneezeweed		X
	Helenium puberulum	Rosilla	X	
	Hemizonia lobbii	Tarweed	X	X
	Hemizonia pungens ssp. *maritima*	Common Spikeweed		X

FAMILY	SPECIES	COMMON NAME	OBSERVED 1973-74 [2]	OBSERVED 1977-78 [3]
	Heterotheca grandiflora	Telegraph Weed	X	X
	Hypochaeris glabra	Smooth Cat's-ear		X
	Isocoma menziesii var. *vernonoides*	Coastal Isocoma	X	
	Lactuca serriola	Prickly lettuce	X	X
	Lasthenia glabrata	Yellow-ray Goldfields	X	X
	Monolopia major	Cupped Monolopia	X	X
	Picris echioides	Bristly Ox-tongue	X	X
	Senecio vulgaris	Common Groundsel	X	X
	Silybum marianum	Milk Thistle	X	X
	Sonchus asper ssp. *asper*	Prickly Sow Thistle		X
	Sonchus oleraceus	Common Sow Thistle		X
	Tragopogon porrifolius	Salsify	X	X
	Xanthium strumarium	Rough Cocklebur	X	X
Azollaceae	*Azolla filiculoides*	Mosquito Fern		X
Betulaceae	*Alnus rhombifolia*	White Alder	X	X
Boraginaceae	*Amsinkia lycopsoides*	Bugloss Fiddle-neck	X	X
	Amsinkia menziesii	Rancher's Fireweed	X	X
	Heliotropium curassavicum	Heliotrope	X	X
Brassicaceae	*Brassica juncea*	Indian Mustard	X	
	Brassica nigra	Black Mustard	X	
	Hirschfeldia incana	Mediterranean Mustard		X
	Lepidium latifolium	Broad-leaf Peppergrass		X
	Lepidium nitidum	Shining Peppergrass		X
	Raphanus sativus	Radish		X
	Sisymbrium officinale	Hedge Mustard		X
Caprifoliaceae	*Lonicera involucrata*	Four-line Honeysuckle	X	X
Caryophyllaceae	*Silene gallica*	Common Catchfly	X	X
	Stellaria pallida	Common Chickweed	X	X
Chenopodiaceae	*Atriplex triangularis*	Spearscale		X
	Atriplex semibaccata	Australian saltbush	X	X
	Chenopodium ambrosioides	American Wormseed		X
	Chenopodium macrospermum var. *halophilum*	Coast Goosefoot		X
	Salicornia subterminalis	Common Glasswort	X	
	Salicornia virginica	Pickleweed	X	X

FAMILY	SPECIES	COMMON NAME	OBSERVED 1973-74 [2]	OBSERVED 1977-78 [3]
	Salsola tragus	Tumbleweed	X	X
Convolvulaceae	*Calystegia sepium* ssp. *limnophila*	Hedge bindweed	X	X
	Convolvulus arvensis	Bindweed	X	X
	Cressa truxillensis	Alkali Weed	X	
Cucurbitaceae	*Marah fabaceus*	California Man-root	X	X
Cyperaceae	*Carex barbarae*	Santa Barbara Sedge		X
	Cyperus eragrostis	Tall Flatsedge		X
	Scirpus acutus var. *occidentalis*	Tule	X	X
	Scirpus californicus	California Bulrush		X
	Scirpus americanus	Olney's Bulrush	X	X
	Scirpus robustus	Alkali Bulrush	X	X
Dipsacaceae	*Dipsacus fullonum*	Wild Teasel	X	
Equisetaceae	*Equisetum arvense*	Common Horsetail	X	X
	Equisetum hymale ssp. *affine*	Common Scouring Rush		X
	Equisetum laevigatum	Smooth Scouring Rush	X	
Euphorbiaceae	*Eremocarpus setigerus*	Dove Weed	X	X
Fabaceae	*Hoita macrostachya*	Leather Root	X	X
	Lathyrus jepsonii var. *jepsonii*	Delta Tule Pea	X	X
	Lotus corniculatus	Birds-foot Trefoil	X	X
	Lotus purshianus var. *purshianus*	Spanish Clover		X
	Lotus scoparius	California Broom		X
	Lupinus succulentus	Arroyo Lupine		X
	Medicago polymorpha	California Burclover	X	X
	Melilotus alba	White sweetclover	X	X
	Melilotus indica	Sourclover		X
	Trifolium gracilentum	Pin-point Clover	X	
	Trifolium repens	White Clover	X	
Fabaceae	*Trifolium willdenovii*	Tomcat Clover	X	X
	Trifolium wormskioldii	Cow Clover		X
Frankeniaceae	*Frankenia salina*	Alkali Heath	X	X
Gentianaceae	*Centaurium muehlenbergii*	Monterey Centaury	X	X
Geraniaceae	*Erodium botrys*	Long-beaked filaree	X	X
	Erodium cicutarium	Red-stemmed Filaree	X	X
	Erodium moschatum	White-stemmed Filaree	X	X
Juglandaceae	*Juglans californica* var. *hindsii*	California Black Walnut	X	X

FAMILY	SPECIES	COMMON NAME	OBSERVED 1973-74 [2]	OBSERVED 1977-78 [3]
Juncaceae	*Juncus balticus*	Baltic Rush		X
	Juncus phaeocephalus var. *paniculatus*	Brown-headed Rush		X
Lamiaceae	*Lycopus americanus*	American Bugleweed		X
	Marrubium vulgare	Common Horehound		X
	Mentha piperita	Peppermint		X
	Stachys albens	White-stem Hedgenettle		X
Liliaceae	*Asparagus officinalis* ssp. *officinalis*	Garden Asparagus	X	X
	Dichelostemma capitatum	Blue Dicks		X
	Triteleia laxa	Ithuriel's Spear		X
Lythraceae	*Lythrum californicum*	California Loosestrife	X	X
	Lythrum hyssopifolium	Hyssop Loosestrife		X
Malvaceae	*Malva parviflora*	Cheeseweed	X	
Moraceae	*Ficus carica*	Fig		X
Oleaceae	*Fraxinus latifolia*	Oregon Ash	X	X
Onagraceae	*Camissonia micrantha*	Small Primrose	X	X
	Epilobium brachycarpum	Panicled Willow Herb	X	X
	Epilobium ciliatum ssp. *ciliatum*	California Willow Herb		X
Papaveraceae	*Eschscholzia californica*	California Poppy		X
Plantaginaceae	*Plantago subnuda*	Mexican Plantain	X	X
	Plantago lanceolata	English Plantain	X	
Poaceae	*Agrostis viridus*	Water Bent Grass	X	X
	Arundo donax	Giant Reed		X
	Avena barbata	Slender Wild Oat		
	Avena fatua	Wild Oat	X	
	Bromus diandrus	Ripgut Grass	X	X
	Bromus hordeaceus	Soft Brome	X	X
	Bromus japonicus	Japanese Brome	X	
	Bromus madritensis ssp. *rubens*	Foxtail Chess	X	X
	Crypsis schoenoides	Swamp Timothy	X	
	Cynodon dactylon	Bermuda Grass	X	X
	Deschampsia cespitosa ssp. *holciformis*	Tufted Hair Grass		X
	Distichlis spicata	Saltgrass	X	X
	Echinochloa crus-galli	Barnyard Grass		X

FAMILY	SPECIES	COMMON NAME	OBSERVED 1973-74 [2]	OBSERVED 1977-78 [3]
	Elymus stebbensii	Wheatgrass	X	
	Hordeum jubatum	Foxtail Barley	X	X
	Hordeum marinum ssp. *glaucum*	Foxtail Barley	X	
	Hordeum marinum ssp. *gussoneanum*	Meditteranean Barley		X
	Hordeum murinum ssp. *leporinum*	Farmer's Foxtail		X
Poaceae	*Koeleria phleoides*	Bristly koeleria	X	
	Leymus triticoides	Creeping Wild-rye		X
	Lolium multiflorum	Italian Ryegrass	X	X
	Paspalum dilatatum	Dallis Grass	X	X
	Phragmites australis	Common Reed	X	X
	Poa annua	Annual Bluegrass	X	X
	Polypogon monspeliensis	Annual Rabbit-foot Grass		X
	Setaria gracilis	Knotroot Bristle Grass		X
	Vulpia bromoides	Six-weeks Fescue	X	X
	Vulpia myuros var. *hirsuta*	Rattail Fescue	X	X
Polygonaceae	*Polygonum arenastrum*	Common Knotweed	X	X
	Polygonum punctatum	Water Smartweed	X	X
	Rumex conglomeratus	Green Dock		X
	Rumex crispus	Curly Dock	X	X
Portulacaceae	*Calandrinia ciliata*	Red Maids		X
	Claytonia perfoliata	Miner's Lettuce		X
	Claytonia exigua ssp. *exigua*	Common Claytonia		X
Potamogetonaceae	*Ruppia maritima*	Widgeon-grass		X
Primulaceae	*Centunculus minimus*	Chaffweed		X
Rosaceae	*Malus sylvestris*	Apple	X	
	Prunus dulcis	Almond	X	
	Rosa californica	California Rose	X	X
	Rubus discolor	Himalayan Blackberry		X
	Rubus ursinus	California Blackberry	X	
Rubiaceae	*Cephalanthus occidentalis* var. *californicus*	California Button-willow	X	X
Salicaceae	*Populus fremontii* ssp. *fremontii*	Fremont Cottonwood	X	X
	Salix goodingii	Gooding's Black Willow	X	X
	Salix exigua	Narrow-leaved Willow	X	X

FAMILY	SPECIES	COMMON NAME	OBSERVED 1973-74 [2]	OBSERVED 1977-78 [3]
	Salix laevigata	Red Willow	X	X
	Salix lucida spp. *lasiandra*	Shining Willow		X
	Salix lasiolepis	Arroyo Willow	X	X
Scrophulariaceae	*Castilleja exserta*	Purple Owl's Clover		X
	Mimulus guttatus	Common Monkeyflower	X	X
Solanaceae	*Solanum americanum*	Small-flowered Nightshade	X	X
Tamaricaceae	*Tamarix parviflora*	Tamarisk	X	
Typhaceae	*Typha angustifolia*	Narrow-leaved cattail	X	X
	Typha domingensis	Southern Cattail		X
	Typha latifolia	Broad-leaved Cattail		X
Urticaceae	*Urtica urens*	Dwarf Nettle		X

[1] Nomenclature follows Hickman (1993)
[2] Based on floristic surveys conducted by Jones & Stokes Associates, Inc (1975)
[3] Based on floristic surveys conducted by BioSystems Analysis, Inc. (1980)
[4] Shaded entries are non-native species

APPENDIX D. RESULTS OF WILDLIFE SURVEYS OF MONTEZUMA ENHANCEMENT SITE

COMMON NAME	SPECIES	OBSERVED 1973-74 [1]	OBSERVED 1975-1978 [2]	OBSERVED 1994
AMPHIBIANS AND REPTILES				
Western Toad	*Bufo boreas*		X	
Pacific Treefrog	*Hyla regilla*	X	X	
Bullfrog	*Rana catesbiana*		X	
Northwestern Pond Turtle	*Clemmys marmota marmota*	X	X	
Southern Alligator Lizard	*Gerrhonotus multicarinatus*	X	X	
Western Fence Lizard	*Sceloperus occidentalis*	X		
Rubber Boa	*Charina bottae*	X		
Racer	*Coluber constrictor*		X	
Gopher Snake	*Pituophis melanoleucus*	X	X	
Common Garter Snake	*Thamnophis sirtalis*	X	X	
BIRDS				
Common Loon	*Gavia immer*	X		
Horned Grebe	*Podiceps auritius*	X		
Eared Grebe	*Podiceps nigricollis*	X		
Western Grebe	*Aechmorphorus occidentalis*	X		
Pied-billed Grebe	*Podilymbus podiceps*	X		X
American White Pelican	*Pelecanus erythrorhynchos*			
Double-crested Cormorant	*Phalacrocorax auritus*	X	X	X
Great Blue Heron	*Ardea herodias*	X	X	X
Great Egret	*Casmerodius albus*	X		X
Black-crowned Night-Heron	*Nycticorax nycticorax*	X		
American Bittern	*Botaurus lentiginosus*	X	X	
Tundra Swan	*Cygnus columbianus*		X	
Canada Goose	*Branta canadensis*	X	X	
Greater White-fronted Goose	*Anser albifrons*	X		
Snow Goose	*Chen caerulescens*	X		
Mallard	*Anas platyrhynchos*	X	X	X
Gadwall	*Anas strepera*	X		
Pintail	*Anas acuta*	X	X	
Green-winged Teal	*Anas crecca*	X	X	
Blue-winged Teal	*Anas discors*		X	
Cinnamon Teal	*Anas cyanoptera*	X	X	
American Widgeon	*Anas americana*	X		
Northern Shoveler	*Anas clypeata*	X	X	
Redhead	*Aythya americana*	X		
Ring-necked Duck	*Aythya collaris*	X		
Canvasback	*Aythya valisneria*	X		
Lesser Scaup	*Aythya affinis*	X		
Common Goldeneye	*Bucephala clangula*	X		
Ruddy Duck	*Oxyura jamaicensis*	X		
Turkey Vulture	*Cathartes aura*	X	X	X
Black-shouldered Kite	*Elanus caeruleus*	X	X	X
Sharp-shinned Hawk	*Accipiter striatus*	X		
Cooper's Hawk	*Accipiter cooperii*	X		
Red-tailed Hawk	*Buteo jamaicensis*	X	X	X
Red-shouldered Hawk	*Buteo lineatus*	X		
Swainson's Hawk	*Buteo swainsoni*	X		
Rough-legged Hawk	*Buteo lagopus*	X	X	
Ferruginous Hawk	*Buteo regalis*	X		X
Golden Eagle	*Aquila chrysaetos*	X	X	
Northern Harrier	*Circus cyaneus*	X	X	X

COMMON NAME	SPECIES	OBSERVED 1973-74 [1]	OBSERVED 1975-1978 [2]	OBSERVED 1994
BIRDS				
Prairie Falcon	*Falco mexicanus*	X	X	X
American Kestrel	*Falco sparverius*	X	X	X
California Quail	*Callipepla californica*	X	X	
Ring-necked Pheasant	*Phasianus colchicus*	X	X	X
Virginia Rail	*Rallus limicola*	X	X	
Sora	*Porzana carolina*	X	X	
Common Moorhen	*Gallinula chloropus*	X		X
American Coot	*Fulica americana*	X	X	X
Killdeer	*Charadrius vociferus*	X	X	
Common Snipe	*Gallinago gallinago*	X		
Long-billed Curlew	*Numenius americanus*	X	X	
Spotted Sandpiper	*Actitis macularia*	X		
Greater Yellowlegs	*Tringa melanoleuca*	X		
Lesser Yellowlegs	*Tringa flavipes*		X	
Least Sandpiper	*Caldris minutilla*	X	X	
American Avocet	*Recurvirostra americana*	X		
Black-necked Stilt	*Himantopus mexicanus*	X	X	
Glaucous Gull	*Larus hyperboreus*	X		
Herring Gull	*Laurus argentatus*	X	X	
California Gull	*Larus californicus*	X	X	X
Ring-billed Gull	*Larus delawarensis*	X		
Forster's Tern	*Sterna forsteri*		X	
Caspian Tern	*Sterna caspia*	X		
Rock Dove	*Columba livia*	X		X
Mourning Dove	*Zenaida macroura*	X	X	X
Common Barn Owl	*Tyto alba*	X	X	
Short-eared Owl	*Asio flammeus*	X		
Great Horned Owl	*Bubo virginianus*	X		X
Burrowing Owl	*Athene cunicularia*	X	X	
Anna's Hummingbird	*Calypte anna*	X	X	
Rufous Hummingbird	*Selasphorus rufus*	X		
Belted Kingfisher	*Ceryle alcyon*			X
Northern Flicker	*Colaptes auratus*		X	X
Acorn Woodpecker	*Melanerpes formicivorus*	X		
Red-breasted Sapsucker	*Sphyrapicus ruber*	X		
Downy Woodpecker	*Picoides pubescens*	X	X	
Lewis' Woodpecker	*Melanerpes lewis*	X		
Western Kingbird	*Tyrannus verticalis*	X	X	
Ash-throated Flycatcher	*Myiarchus cinerascens*	X		
Black Phoebe	*Sayornis nigricans*	X		X
Say's Phoebe	*Sayornis saya*	X	X	
Willow Flycatcher	*Empidonx traillii*	X		
Western Wood Pewee	*Contopus sordidulus*	X		
Horned Lark	*Eremophila alpestris*	X	X	
Violet-green Swallow	*Tachycinetta thalassina*	X	X	
Tree Swallow	*Tachycinetta bicolor*	X		
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*		X	
Barn Swallow	*Hirundo rustica*	X	X	
Scrub Jay	*Aphelocoma coerulescens*	X		
Common Raven	*Corvus corax*	X		
Common Crow	*Corvus brachyrynchos*	X	X	
Bushtit	*Psaltriparus minimus*	X	X	
House Wren	*Troglodytes aedon*	X	X	

COMMON NAME	SPECIES	OBSERVED 1973-74 [1]	OBSERVED 1975-1978 [2]	OBSERVED 1994
BIRDS				
Bewick's Wren	*Thryomanes bewickii*		X	
Marsh Wren	*Cistothorus palustris*	X	X	X
Northern Mockingbird	*Mimus polyglottos*	X	X	X
American Robin	*Turdus migratorius*	X	X	X
Hermit Thrush	*Catharus guttatus*	X		
Blue-gray Gnatcatcher	*Polioptila caerulea*	X		
Golden-crowned Kinglet	*Regulus satrapa*	X		
Ruby-crowned Kinglet	*Regulus calendula*	X	X	
Water Pipit	*Anthus spinoletta*	X	X	
Loggerhead Shrike	*Lanius ludovicianus*	X	X	X
European Starling	*Sturnus vulgaris*	X	X	X
Solitary Vireo	*Vireo solitarius*	X		
Orange-crowned Warbler	*Vermivora celata*		X	
Yellow-rumped Warbler	*Dendroica coronata*	X	X	
Yellow Warbler	*Dendroica petechia*	X		
Townsend's Warbler	*Dendroica townsendi*	X		
Black-throated Gray Warbler	*Dendroica nigrescens*		X	
MacGillivray's Warbler	*Oporornis tolmiei*	X		
Common Yellowthroat	*Geothlypis trichas*	X	X	
Wilson's Warbler	*Wilsonia pusilla*	X	X	
House Sparrow	*Passer domesticus*	X	X	
Western Meadowlark	*Sturnella neglecta*	X	X	X
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*	X		
Red-winged Blackbird	*Agelaius phoeniceus*	X	X	X
Tricolored Blackbird	*Agelaius tricolor*		X	
Brewer's Blackbird	*Euphagus cyanocephalus*	X	X	X
Brown-headed Cowbird	*Molothrus ater*	X		
Western Tanager	*Piranga ludoviciana*	X		
Black-headed Grosbeak	*Pheuticus melanocephalus*		X	
Purple Finch	*Carpodacus purpureus*		X	
House Finch	*Carpodacus mexicanus*	X	X	X
American Goldfinch	*Carduelis tristis*	X	X	
Lesser Goldfinch	*Carduelis psaltria*	X	X	
Rufous-sided Towhee	*Pipilo erythrophthalmus*	X	X	
Brown Towhee	*Pipilo fuscus*	X	X	X
Savannah Sparrow	*Passerculus sandwichensis*	X	X	X
Lark Sparrow	*Chondestes grammacus*	X		
Dark-eyed Junco	*Junco hyemalis*	X	X	X
Grasshopper Sparrow	*Ammodramus savannarum*		X	
White-crowned Sparrow	*Zonotrichia leucophrys*	X	X	
Golden-crowned Sparrow	*Zonotrichia atricapilla*	X	X	
White-throated Sparrow	*Zonotrichia albicollis*	X		
Fox Sparrow	*Passerella iliaca*	X		
Lincoln's Sparrow	*Melospiza lincolnii*		X	
Song Sparrow	*Melospiza melodia*	X	X	
Suisun Song Sparrow	*Melospiza melodia maxillaris*		X	
MAMMALS				
Common Opossum	*Didelphis marsupialis*		X	X
Black-tailed Hare	*Lepus californicus*	X	X	X
Audubon Cottontail	*Sylvilagus auduboni*	X	X	X
Beechy Ground Squirrel	*Spermophilus beecheyi*	X	X	X
Botta Pocket Gopher	*Thomomys bottae*	X	X	
Beaver	*Castor canadensis*		X	

COMMON NAME	SPECIES	OBSERVED 1973-74 [1]	OBSERVED 1975-1978 [2]	OBSERVED 1994
MAMMALS				
Western Harvest Mouse	*Reithrodontomys megalotis*	X	X	X
Salt Marsh Harvest Mouse	*Reithrodontomys raviventris*		X	
Deer Mouse	*Peromyscus maniculatus*	X	X	
California Meadow Mouse	*Microtus californicus*	X	X	
Muskrat	*Ondrata zibethica*	X	X	
Norway Rat	*Rattus norvegicus*	X		
Black Rat	*Rattus rattus*		X	
House Mouse	*Mus musculus*	X	X	X
Coyote	*Canis latrans*	X	X	X
Red Fox	*Vulpes fulva*		X	X
Gray Fox	*Urocyon cinereoargentus*	X	X	
Raccoon	*Procyon lotor*	X	X	X
Long-tailed Weasel	*Mustela frenata*	X		
River Otter	*Lutra canadensis*	X		X
Badger	*Taxidea taxus*		X	
Spotted Skunk	*Spilogale putorius*	X		
Striped Skunk	*Mephitis mephitis*	X	X	
Bobcat	*Lynx rufus*		X	
Black-tailed Deer	*Odocoileus hemionus*		X	

[1] Based on surveys conducted by Jones & Stokes Associates, Inc. (1975)
[2] Based on surveys conducted by BioSystems Analysis, Inc. (1980) and Ficket (1976)

APPENDIX E. CIRCULATING WATER PUMP VARIABLE SPEED DRIVE (VSD) OPERATION

The circulating water pumps at Delta Power Plants are mixed flow vertical centrifugal pumps equipped with A-C induction motor drives. The drives have been modified to utilize variable speed drive (VSD) controls, as well as to operate at full rated speed. The VSD controls provide a means to vary drive speed by varying frequency. For a centrifugal pump, flow is proportional to pump speed. Therefore as frequency and drive/pump speed are reduced, pump flow is also reduced proportionally (i.e., 50% pump speed => 50% pump flow).

When operating in VSD mode, the circulating water pump speed/flow is typically at its minimum level when the unit is at minimum load. For Pittsburg Power Plant Units 1-4, minimum load is ~30 - 35 megawatts (MW) and minimum pump speed/flow is 70% of design. The minimum circulating water pump speed/flow is limited by both the pump & motor design and the system head requirements. For Pittsburg Power Plant Units 5 & 6 and Contra Costa Power Plant Units 6 & 7 minimum flow is 50% of design and minimum load is ~25 - 45 MW. As unit load increases, pump speed and flow are increased in accordance with unit conditions. Maximum circulating water speed/flow, 95 - 100% of design, is typically reached at ~45 - 60 MW for Pittsburg Power Plant Units 1-4 and at ~90 - 145 MW for Pittsburg Power Plant Units 5 & 6 and Contra Costa Power Plant Units 6 & 7. River water temperature, tide, condenser vacuum, steam flow, etc., all have an effect on circulating water flow requirements. The controls may include overrides and/or trips off VSD, for unit/equipment protection.

During February 1 through July 31, the circulating water pumps on Pittsburg Power Plant Units 1-6 & Contra Costa Power Plant Units 6 & 7 will be operated in VSD mode when the units are operating under the following conditions:

- Minimum load
- Manual (operator controlled) loading up to 50% of rated capacity
- Low Range Automatic (remote) Generation Control (AGC)

The circulating water pumps will be operated in bypass mode when flow reductions are not achievable, when the units are operated under the following conditions:

- Full load
- Manual loading above 50%
- High Range AGC

The current operating ranges for Low Range and High Range AGC are below:

	Low Range AGC	High Range AGC
CCPP Units 6 & 7	60 - 180 MW	130 - 325 MW
PPP Units 1-4	28 - 78 MW	78 - 150 MW
PPP Units 5 & 6	60 - 160 MW	135 - 300 MW

These operating conditions were modeled using past operational data to evaluate potential flow reductions achievable by running circulating water pumps in VSD mode. Table E-1 shows the potential flow differences between use of VSDs versus actual operational flows for selected years between 1990 and 1997 for Contra Costa and Pittsburg Power Plants. Table E-2 provides data showing the percentage of total actual circulating water pump design flow for the years 1987-1997 for Contra Costa and Pittsburg Power Plants.

Table E-1

Flow[1] Difference between use of VSD's and Actual Operation by Month[2] for Selected Years

(Highlighted cells indicate months when VSD operation resulted in flow reductions which would not have been required under a simple flow maximum.)

Contra Costa Power Plant Units 6 & 7

Month/Operational Mode		Year					
		1990	1991	1993	1994	1995	1997
February	Actual Flow[2]	98	96	99	91	30	51
	Calc. VSD Flow	84	86	92	87	26	41
	Difference	14	10	7	4	4	10
March	Actual Flow	55	99	99	88	25	45
	Calc. VSD Flow	45	94	88	83	21	38
	Difference	10	5	11	5	4	7
April	Actual Flow	43	77	74	97	12	44
	Calc. VSD Flow	38	64	58	93	10	38
	Difference	5	13	16	4	2	6

Pittsburg Power Plant Units 1 -7

Month/Operational Mode		Year					
		1990	1991	1993	1994	1995	1997
February	Actual Flow[2]	79	80	76	64	28	20
	Calc. VSD Flow	72	70	67	60	20	15
	Difference	7	10	9	4	8	5
March	Actual Flow	82	84	61	58	25	26
	Calc. VSD Flow	71	74	53	52	20	20
	Difference	11	10	8	6	5	6
April	Actual Flow	86	91	50	80	21	34
	Calc. VSD Flow	81	76	37	77	18	27
	Difference	5	15	13	3	3	7

[1] Percent of design flow

[2] Only Feb. through April are shown because May through July flows are already reduced through use of VSD's as required under the Resources Management Program to reduce losses of striped bass due to entrainment.

Table E-2
Contra Costa Power Plant Units 6 & 7

Average Monthly CW Flow, % of Design

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	Average Flow
FEB	95	50	96	98	96	50	99	91	30	54	51	74
MAR	99	61	37	55	99	55	99	88	25	44	45	64
APR	60	77	38	43	77	78	74	97	12	16	44	56
MAY	77	94	49	41	44	29	17	11	0	22	46	39
JUN	72	94	35	52	43	63	31	22	44	38	43	49
JUL	98	100	70	72	64	84	62	95	38	69	60	74

Pittsburg Power Plant Units 1 - 7

Average Monthly CW Flow, % of Design

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	Average Flow
FEB	79	61	89	79	80	60	76	64	28	26	20	60
MAR	68	97	85	82	84	79	61	58	25	22	26	62
APR	77	88	79	86	91	66	50	80	21	24	34	63
MAY	68	80	25	56	35	39	15	23	12	19	35	37
JUN	75	72	45	33	25	39	27	22	20	30	25	38
JUL	63	88	82	64	53	72	27	61	28	57	35	57

APPENDIX F. MITIGATION COMPENSATION PROGRAM

Power plant cooling water intake will be limited below the design capacity of the circulating water pumps through use of variable speed drive (VSD) controls on the circulating water pumps. Future system demands may on occasion require full power production and maximum cooling water system flow to meet system reliability needs. At such time the units would be required to run at full speed and variable speed drive would not be feasible and the cooling water intake threshold of 80% of design flow at the Pittsburg Power Plant Units 1-7 and 95% of design flow at the Contra Costa Power Plant Units 6 and 7 may be exceeded. The methods for determining required compensation mitigation for Delta smelt and winter-run chinook salmon are described below. Appropriate methods for other species in the HCP will be developed as needed. However, the total annual mitigation compensation amount will be limited to a maximum amount of $100,000 per power plant. The final annual mitigation amount will calculated, typically near November, after the fall mid-water trawl index for Delta smelt is released.

METHOD FOR ASSESSING COMPENSATION FOR DELTA SMELT

Compensation is determined based on four factors:

a. the degree to which the power plants exceed prescribed circulating water flow thresholds,
b. the amount of compensation per percentage points of exceedance,
c. the abundance of Delta smelt in the area of the power plants, and
d. the abundance of Delta smelt throughout the Delta.

a. Power Plant Operation in Excess of Prescribed Limits

The extent that a power plant exceeds its prescribed threshold flow in any one month was measured as the sum of the percentage points of exceedance of the 7-day running average operation. For example, if the 7-day running average exceeded the 95% threshold at the Contra Costa Power Plant by a total of 10% over 10 days (e.g. 1% per day) during a month then the percentage points of exceedance for the month would be 10. Full operation (100%) for a 30-day month would be 150 percentage points of exceedance (30 times 5).

b. Compensation Amount Based upon Level of Exceedance

Based on the 7-day running average of cooling water flow, the mitigation amounts per percentage point of exceedance were determined for each power plant for a maximum potential mitigation of $1,500 per day when cooling water flow is at design levels (100%). This resulted in $75 per percentage point of exceedance at Pittsburg Power Plant and $300 per percentage point of exceedance at Contra Costa Power Plant.

c. Abundance of Delta Smelt in the Area of the Power Plants

February through July occurrence of Delta smelt near the power plants is best measured from agency surveys in the Bay-Delta:

- Egg and Larvae Survey
- Summer Townet Survey
- Real-Time Monitoring Townet Survey
- 20-mm Townet Survey
- Beach Seine Survey (part of the Juvenile Migration Survey)
- Salmon Trawl Survey at Chipps Island (part of the Juvenile Migration Survey)
- Fall Mid-Water Trawl Survey

Of these surveys, only the first four provide adequate catches of Delta smelt in the February through July period of greatest susceptibility to the plants. Each of these four surveys provides an independent index of Delta smelt abundance near the plants and throughout Bay-Delta survey area. Each survey has a different survey design in terms of sampling locations and frequency. For this reason, an index of abundance of the population near the plants for a particular month is calculated for each survey by dividing the catch near the plant that month by the total survey catch for the season. This serves to incorporate the importance of the area near a power plant by month relative to the Bay-Delta population throughout the year. In short, each month's catch near a power plant is weighted by the total catch for the season.

Rather than provide four independent indices of abundance, the average of the four indices was used as the measure of risk at the respective power plant. For a two survey example, one survey caught 8 Delta smelt for a month near Pittsburg and the total catch for the entire survey (all sites and all months sampled) was 300 Delta smelt. A second survey caught 2 Delta smelt in the same month near Pittsburg and the total survey catch (all sites) for that year was 150 Delta smelt. For each survey, the proportion caught near Pittsburg is calculated by dividing the number caught near Pittsburg by the entire survey catch (8/300 and 2/150). The Pittsburg Delta smelt index would be the average of those two proportions (6/300).

The sites selected from each survey were those located within one tidal excursion of each plant. The tidal excursions were 10 miles and 8 miles at Pittsburg and Contra Costa, respectively. All survey locations upstream and downstream for those distances were included. Surveys that sampled at least part of the February through July period were included. Survey sites that had little or no sampling within the last 10 years were excluded. For each survey, all sites considered near a power plant (± tidal excursion distance) and not excluded due to limited sampling were added together (e.g., the summer townet survey had 6 sites near Pittsburg; for each month the catches at those 6 sites were added to give a total catch near Pittsburg). Near the Contra Costa Power Plant, the summer townet survey had 2 sites, the striped bass egg and larvae survey had 5 sites, the 20mm survey had 4 sites, and the real-time survey had 1 site (Table F-1). Near the Pittsburg

Power Plant, the summer townet survey had 6 sites, the striped bass egg and larvae survey had 8 sites, the 20mm survey had 6 sites, and the real-time survey had 1 site (Table F-1).

Table F-1. Surveys and Survey Sites Used (or proposed to be used as data become available) in Determining Delta Smelt Abundance Near the Pittsburg and Contra Costa Power Plants

Survey	Local Survey Locations	
	Pittsburg Power Plant	Contra Costa Power Plant
Real-Time Monitoring Program [1]	Chipps Island	Jersey Point
20-mm Townet Survey [1]	504, 508, 513, 519, 520, 801	703, 802, 804, 809
Striped Bass Egg and Larvae Survey	9, 11, 13, 15, 17, 33, 35, 66	35, 37, 39, 41, 43
Summer Townet Survey	504, 508, 513, 519, 520, 801	804, 809

For the purposes of this simulation, only the egg and larval survey and the summer townet survey data were available. Data from the Real-Time Monitoring and 20-mm Townet Surveys were not available in time to include into our index calculations. These surveys would add to the index calculations, particularly because sampling is more frequent than the Egg and Larvae and Townet Surveys. In addition, as new surveys or new survey locations for the existing surveys become available, they will be evaluated for inclusion into the index calculation. If surveys or survey locations are discontinued, they will be removed from the index calculation. If no surveys are done, then comparable water year type survey results would be used as approved by the Department of Fish and Game and the U.S. Fish and Wildlife Service.

d. Annual Index of Delta Smelt

In addition to smelt abundance near the plant, compensation for exceeding prescribed operation limits would also consider the annual index of abundance of Delta smelt from the fall midwater trawl survey. If the annual production is low, then mitigation compensation would be greater, and visa-versa. A fall midwater trawl Delta smelt index of 235 was defined as a benchmark or critical population level. This level was used in the Biological Opinion for the Delta Wetlands Project as a critical threshold for the population.

ESTIMATING COMPENSATION

Compensation for exceeding circulating water thresholds above predetermined threshold volumes is assessed based on four basic parameters:

a. The extent of operation above the prescribed limits as measured by the number of percentage points the 7-day running average is above the prescribed 80 and 95% circulating water thresholds.

b. The amount of compensation per percentage point of exceedance of the respective 80 and 95% thresholds, $75 for Pittsburg and $300 for Contra Costa per percentage point of exceedance.

c. Survey abundance of Delta smelt by month in the region of each of the power plants; up to four surveys types may be available in any single month. Each survey's abundance is divided by the total Bay-Delta seasonal abundance to factor in local abundance with total population abundance.

d. The annual index of Delta smelt production measured at the end of the season in the Fall Midwater Trawl Survey.

Compensation is assessed as follows:

a. A base level of mitigation is calculated based upon exceeding the cooling water flow threshold (80% of design flow at Pittsburg and 95% of design flow at Contra Costa). The base level mitigation also represents the theoretical maximum mitigation which is adjusted later to incorporate biological information. When the average flow has exceeded the threshold level, the percentage points of exceedance is calculated by subtracting the threshold percentage from the actual 7-day average flow percentage of design.

   Percentage points of exceedance = (7-day average flow/design flow) - 80% (Pittsburg),
   Percentage points of exceedance = (7-day average flow/design flow) - 95% (Contra Costa).

b. The base mitigation amount is the number of percentage points of exceedance the daily 7-day average is above threshold multiplied by $75 for Pittsburg or $300 for Contra Costa (Table F-2). Hence, only when the thresholds have been exceeded, is the daily base level of mitigation calculated as follows.

   Base mitigation = percentage points of exceedance * $75 per percentage point (Pittsburg),
   Base mitigation = percentage points of exceedance * $300 per percentage point (Contra Costa).

Table F-2. Daily Base Mitigation Amounts Based Upon the 7-Day Average Flow Exceeding Threshold Limits (For example, if the Pittsburg Power Plant 7-day average flow exceeded the 80% of design flow threshold for 9 days straight: 82%, 84%, 86%, 88%, 87%, 89%, 86%, 92%, and 90%, respectively. The 9 days would add up to 64 percentage points above the threshold, 2 + 4 + 6 + 8 + 7 + 9 + 6 + 12 + 10 = 64. The resulting mitigation amounts are $150 + $300 + $450 + $600 + $525 + $675 + $ 450 + $900 + $750 = $4,800.)

Pittsburg Power Plant	
Percentage Points above Threshold Level	Mitigation
1	$75
2	$150
3	$225
4	$300
5	$375
6	$450
7	$525
8	$600
9	$675
10	$750
11	$825
12	$900
13	$975
14	$1,050
15	$1,125
16	$1,200
17	$1,275
18	$1,350
19	$1,425
20	$1,500

Contra Costa Power Plant	
Percentage Points above Threshold Level	Mitigation
0.25	$75
0.50	$150
0.75	$225
1.00	$300
1.25	$375
1.50	$450
1.75	$525
2.00	$600
2.25	$675
2.50	$750
2.75	$825
3.00	$900
3.25	$975
3.50	$1,050
3.75	$1,125
4.00	$1,200
4.25	$1,275
4.50	$1,350
4.75	$1,425
5.00	$1,500

A mitigation adjustment is calculated at the end of the year for each month from the local abundance index and the fall midwater trawl Delta smelt index (Table F-3). The adjustment serves to incorporate the local and overall abundance of Delta smelt into the calculation of the mitigation amount. The adjustment is multiplied with the base mitigation to determine actual mitigation for each month at the end of the year,

actual mitigation = base mitigation * mitigation adjustment.

c. The local abundance index is the average survey local area catch divided by the survey's regional catch for the season. The local abundance index represents the fraction of the population that occurs near the power plants in a particular month. An index of 1 means, for the entire season, all surveys and survey sites, Delta smelt were caught only near the power plant and only in that particular month.

d. The fall midwater trawl Delta smelt index is calculated by CDFG and estimates overall Delta smelt abundance. When the fall midwater trawl Delta smelt index is less than or equal to 235 then the population is considered to be at risk and the mitigation adjustment is equal to the local abundance index. However, when the fall midwater trawl index is greater than 235 then the populations is considered to be not at high risk and the mitigation adjustment is one-half the local abundance index (Table F-3). For example, if the local abundance index was 1 and the fall midwater trawl index was low, then the mitigation adjustment would be 1 and the base mitigation would not be affected. However, if the fall midwater trawl index was high, then the mitigation adjustment would be half of the local abundance index and the base mitigation would be reduced by half.

Table F-3. Mitigation Adjustment Factor Based Upon Local and Regional CDFG Survey Data [1]

LOCAL ABUNDANCE INDEX	Mitigation Adjustment	
	Fall Midwater Trawl Delta Smelt Index ≤ 235	Fall Midwater Trawl Delta Smelt Index > 235
1	1	0.5
0.9	0.9	0.45
0.8	0.8	0.4
0.7	0.7	0.35
0.6	0.6	0.3
0.5	0.5	0.25
0.4	0.4	0.2
0.3	0.3	0.15
0.2	0.2	0.1
0.1	0.1	0.05
0.09	0.09	0.045
0.08	0.08	0.04
0.07	0.07	0.035
0.06	0.06	0.03
0.05	0.05	0.025
0.04	0.04	0.02
0.03	0.03	0.015
0.02	0.02	0.01
0.01	0.01	0.005
0	0	0

[1] The local abundance index represents an estimate of the proportion of the Delta smelt population that occurs near the power plants. For a given month, a local abundance index of 1 means out of all of the different surveys and survey locations used, Delta smelt only occurred at the sites near the plants and only in that month. A local abundance of 0.5 means that the surveys estimate that 50% of the Delta smelt population occurred near the power plants for a given month. The adjustment factor is multiplied by the base mitigation amount to determine the actual mitigation amount. Hence, a high local abundance results in a high mitigation amount and a low local abundance results in a low mitigation amount. In addition, the adjustment factor also incorporates CDFG's fall midwater trawl estimate of Delta smelt abundance. If the fall midwater trawl index is greater than 235 then the population is not at dangerously low levels and the mitigation adjustment is half of the local abundance index, which results in reduced mitigation. If the fall midwater trawl index is less than or equal to 235 then the populations is at dangerously low levels and the mitigation adjustment is the same as the local abundance index.

In summary, the resulting mitigation adjustment is equal to the local abundance index when the fall midwater trawl Delta smelt index (FMWT) is less than or equal to 235 and the mitigation adjustment is equal to half of the local abundance estimate when the fall midwater trawl Delta smelt index is greater than 235.

if FMWT <= 235 then the mitigation adjustment = local abundance index,
if FMWT > 235 then the mitigation adjustment = local abundance index / 2.

Example - Based on Pittsburg Power Plant, July of 1990 simulated VSD operational information and actual fisheries monitoring data:

a. July accumulated approximately 4 percentage points above threshold limits.

b. From Table F-2 and the formula above for Pittsburg, the base mitigation would be $300.

c. Two surveys occurred in that month, one survey caught 11 Delta smelt locally in July out of 123 Delta smelt total for the year. The other survey caught 2 Delta smelt locally for July out of 379 Delta smelt total for the year. The local abundance index would be the average of the proportions caught near the power plant, ((11/123)+(2/379))/2, or 0.0473.

d. The fall-midwater trawl Delta smelt index for 1990 was 363 (>235), hence the mitigation adjustment would half of the local abundance index (0.0473/2), or 0.0237, resulting in a mitigation at the end of the year of $8 for July 1990 (formula above and Table F-3).

The resulting equations would be:

Base mitigation = percentage points of exceedance * $75 per percentage point = 4 * $75 = $300
Mitigation adjustment = local abundance index/2 = average(11/123,2/379)/2 = 0.0237
Actual mitigation = base mitigation * mitigation adjustment = $300 * 0.0237 = $8

During the VSD simulation period, abundance indices were typically 0.1 or less. However, at the Pittsburg Power Plant, the maximum index was 0.19, but that occurred during a month where there was no exceedance and, therefore, no compensation.

SIMULATION OF COMPENSATION METHOD

Simulation of Power Plant Circulating Flows under VSD Operation and Exceedance Levels
Figures F-1 and F-2 depict the 7-day running average simulated circulating water flow under VSD operation for each plant. If the 7-day average flow for the Pittsburg Power Plant goes above the 80% of design flow threshold level then the plant accumulates percentage points of exceedance. The exceedance is the percentage points above the threshold level. For example, if the 7-day average flows for a week are 82%, 84%, 85%, 86%, 88%, 85%, and 79% of design flow, then the plant accumulates 2 + 4 + 5 + 6 + 8 + 5, or 30 percentage points of exceedance for that week. The daily percentage points of exceedance were summed together for each month and are presented in the bar graph at the top of Figures F-1, F-2, F-7, and F-8.

Delta Smelt Catch Near Power Plant and in entire Bay-Delta Survey Area
Figures F-3 through F-5 depict local (near power plants) and total catch of Delta smelt by survey and Figure F-6 is a graph of the annual Delta Smelt Fall Midwater Trawl Index. Figures F-3 and F-4 show the catch of Delta smelt near each plant by survey. For each survey, the bars represent the summed catch of Delta smelt for all sites located near a power plant (e.g., if there were 5 Summer Townet sites near Pittsburg in June 1992, then the bar is the sum of the catch of all 5 townets). Figure F-5 depicts the total catch (all sites) of the surveys by month. Local catch data from 1997 was not available in time to include into our index calculations.

Simulation of Compensation
Figures F-7 and F-8 depict the method of estimating compensation for each plant. The monthly exceedance-days were calculated based on the rules discussed above and used in the formulas described above.

Potential Worst Case Annual Mitigation Based on Historical Data
The examples presented here use data provided by the agencies and PG&E during 1990, 1991, 1993, 1994, 1995, and 1997. These years were chosen to reflect a range of circulating water flows and varying water year types (i.e., normal, wet, and dry). These are the same years used in the VSD analysis presented in Appendix E.

The worst conditions for each month were extracted from the data sets to simulate the worst case annual mitigation amount. To clarify, the highest actual percentage points of exceedance in the dataset under VSD operation, the lowest mid-water trawl index, and the highest local abundance index for a given month were selected, independent of each other, such that they may or may not come from the same month in the same year. The lowest annual fall mid-water trawl Delta smelt index to occur within the data set was 101.2.

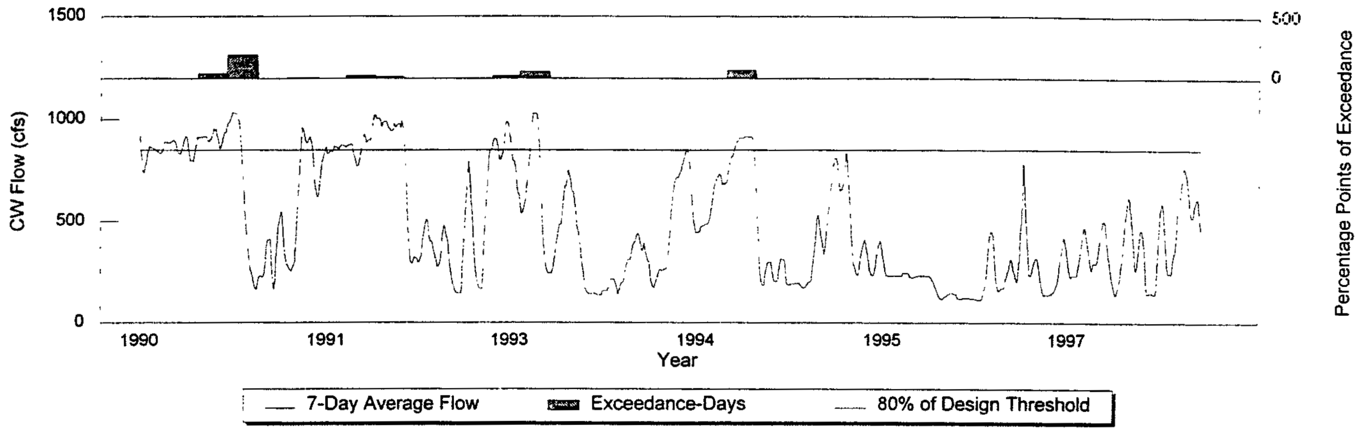

Figure F-1. VSD Cooling Water Circulation Flow at Pittsburg Power Plant for February through July with 80% Threshold Line and Exceedance-Days (1990, 1991, 1993, 1994, 1995, and 1997)

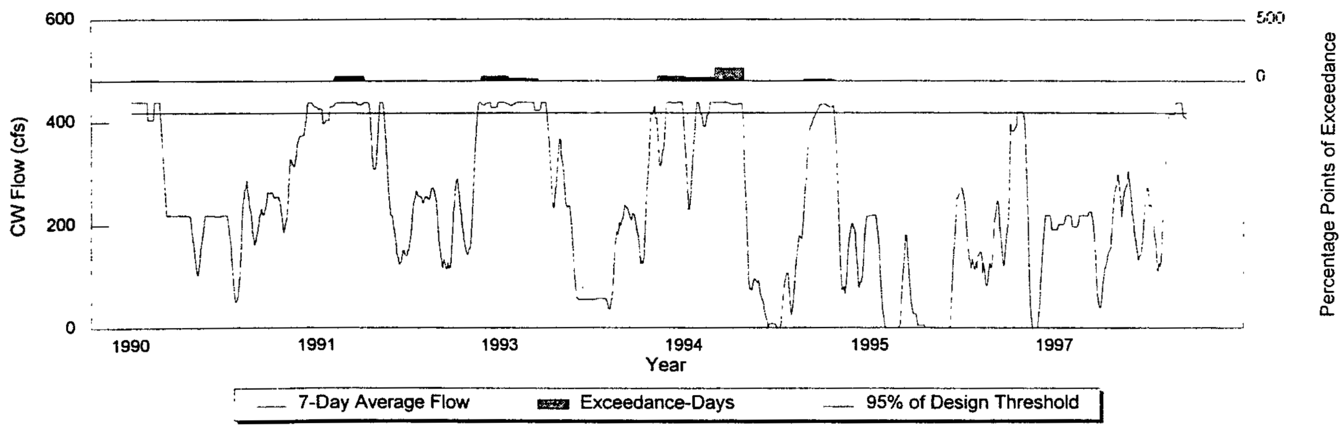

Figure F-2. VSD Cooling Water Circulation Flow at Contra Costa Power Plant for February through July with 95% Threshold Line and Exceedance-Days (1990, 1991, 1993, 1994, 1995, and 1997)

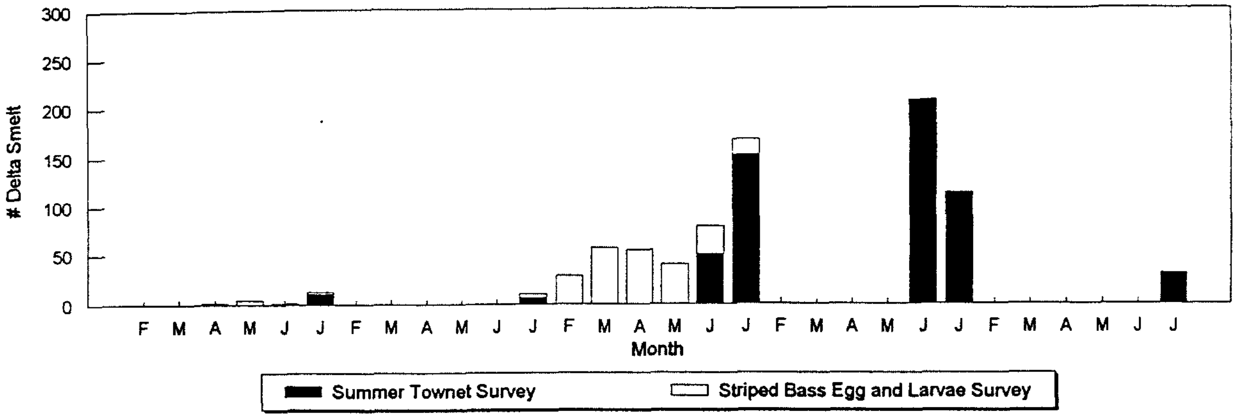

Figure F-3. Total Number of Delta Smelt Caught near the Pittsburg Power Plant for February through July for years 1990, 1991, 1993, 1994, and 1995

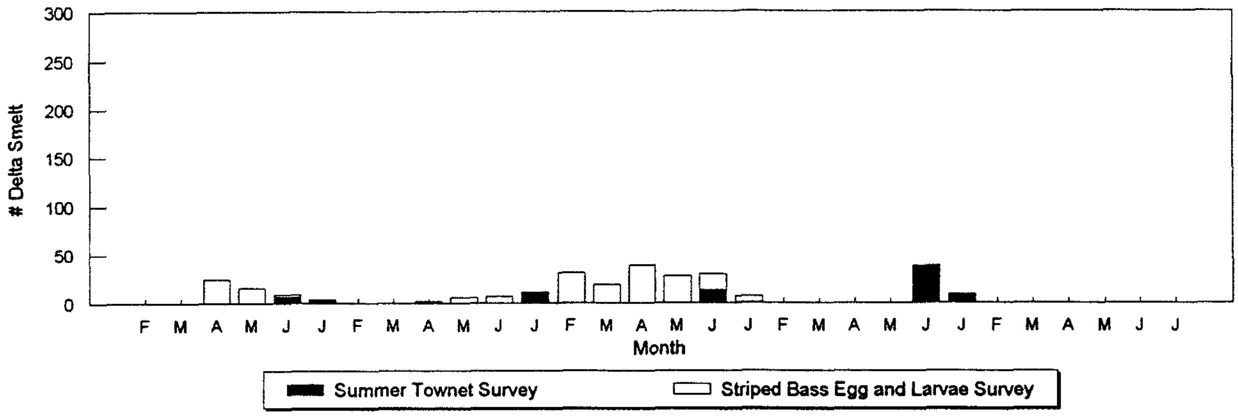

Figure F-4. Total Number of Delta Smelt Caught near the Contra Costa Power Plant for February through July for years 1990, 1991, 1993, 1994, and 1995

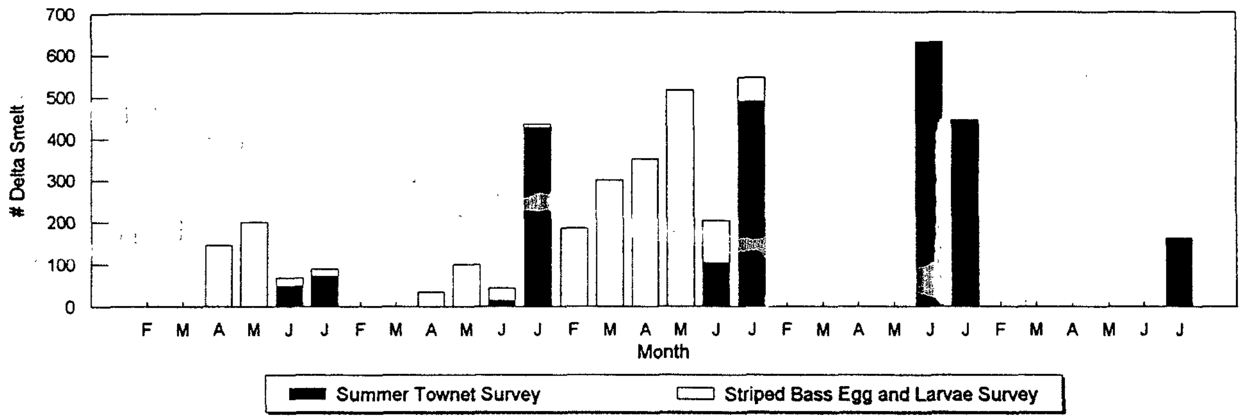

Figure F-5. Total Number of Delta Smelt Caught in the Bay-Delta Area for February through July for years 1990, 1991, 1993, 1994,

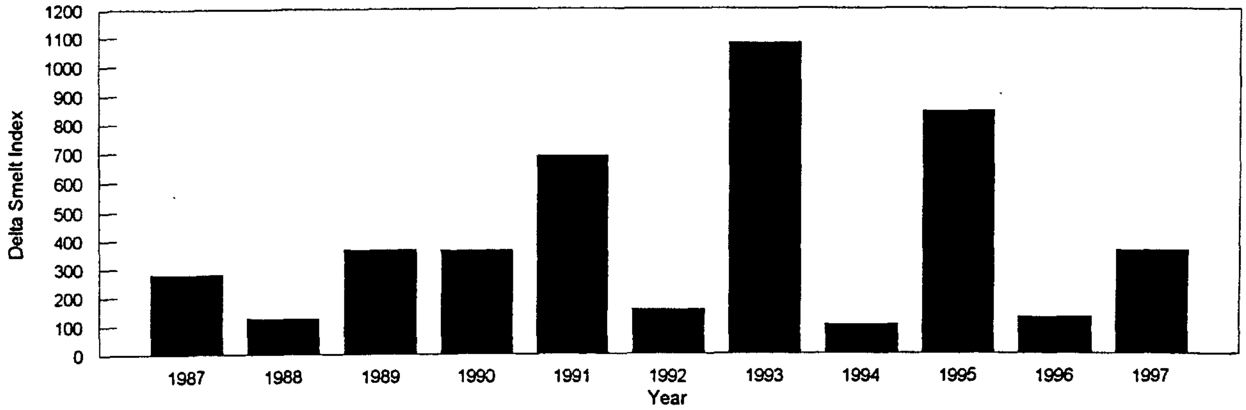

Figure F-6. Annual Delta Smelt Fall Midwater Trawl Index (1987 - 1997).

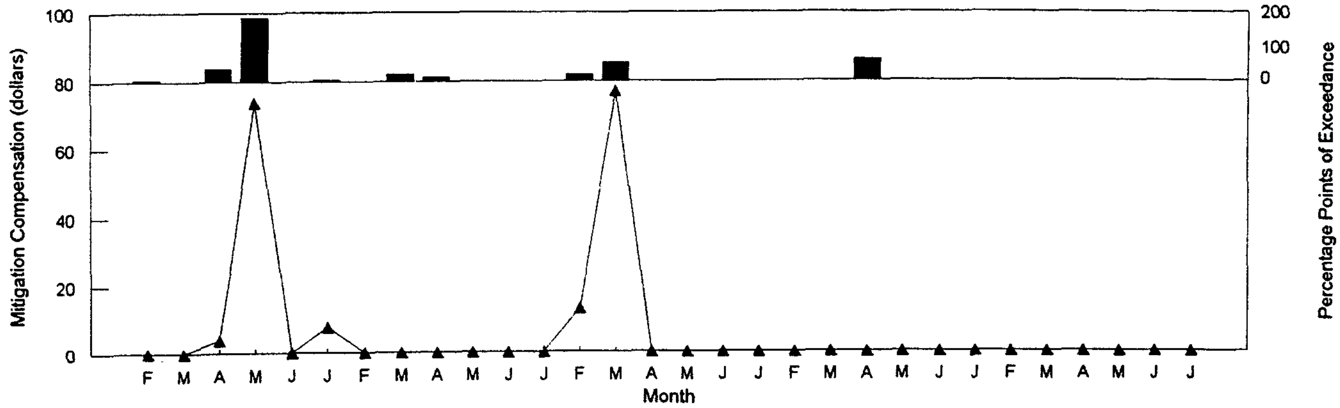

Figure F-7. Monthly Simulation of Compensation at the Pittsburg Powerplant for February through July for 1990, 1991, 1993, 1994, and 1995

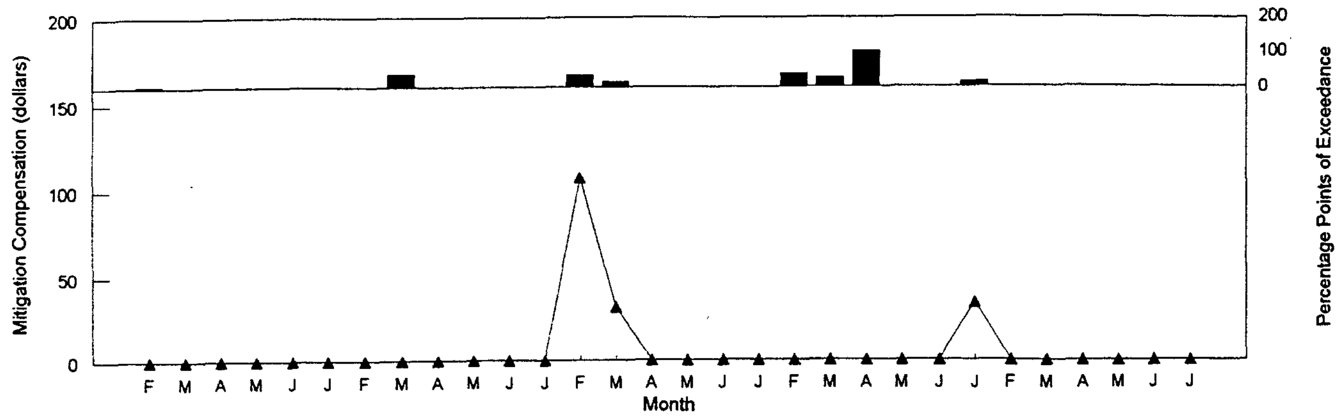

Figure F-8. Monthly Simulation of Compensation at the Contra Costa Powerplant for February through July for 1990, 1991, 1993, 1994, and 1995

Table F-4 illustrates the potential worst case mitigation for the Pittsburg Power Plant based upon the lowest annual fall mid-water trawl Delta smelt index, the highest local abundance index and the maximum cumulative percentage points of exceedance for a month. These numbers are not for any one particular year.

Table F-4. Potential Worst Case Mitigation Amount for Pittsburg Power Plant

MONTH	Fall Mid-water Trawl Index	Abundance Index	Percentage Points	Base Mitigation Level	Mitigation Adjustment	Actual Mitigation
February	101.2	0.019	18.7	$1,403	0.019	$26.65
March	101.2	0.038	54.3	$4,073	0.038	$154.76
April	101.2	0.036	63.1	$4,733	0.036	$170.37
May	101.2	0.027	187.3	$14,048	0.027	$379.28
June	101.2	0.192	0	$0	0.192	$0.00
July	101.2	0.133	4.3	$323	0.133	$42.89
					Total	**$773.95**

Table F-5 illustrates the potential worst case mitigation for the Contra Costa Power Plant based upon the lowest annual fall mid-water trawl Delta smelt index, the highest local abundance index and the maximum cumulative percentage points of exceedance for a month. These numbers are not for any one particular year.

Table F-5. Potential Worst Case Mitigation Amount for Contra Costa Power Plant

MONTH	Fall Mid-water Trawl Index	Abundance Index	Percentage Points	Base Mitigation Level	Mitigation Adjustment	Actual Mitigation
February	101.2	0.021	38.3	$11,490	0.021	$241.29
March	101.2	0.013	38.4	$11,520	0.013	$149.76
April	101.2	0.066	102.6	$30,780	0.066	$2,031.48
May	101.2	0.092	0	$0	0.092	$0.00
June	101.2	0.114	0	$0	0.114	$0.00
July	101.2	0.031	13.5	$4,050	0.031	$125.55
					Total	**$2,548.08**

METHOD FOR ASSESSING COMPENSATION FOR WINTER-RUN CHINOOK SALMON

February and March have been identified as the critical time period for juvenile winter-run chinook salmon in the Delta. Therefore, compensation in February and March is determined by three factors:

a. the degree to which the power plants exceed prescribed circulating water flow thresholds,
b. the amount of compensation per percentage points of exceedance, and
c. the estimated winter-run chinook salmon population size

a. Power Plant Operation in Excess of Prescribed Limits
The extent that a power plant exceeds its prescribed threshold flow in February and March will be measured as the sum of the percentage points of exceedance of the 7-day running average operation. For example, if the 7-day running average exceeded the 95% of design flow threshold at the Contra Costa Power Plant Units 6 and 7 by a total of 10% over 10 days (e.g. 1% per day) during February then the percentage points of exceedance for the month would be 10. Full operation (100%) for a 30-day month would be 150 percentage points of exceedance (30 times 5).

b. Compensation Amount Based upon Level of Exceedance
Based on the 7-day running average of cooling water flow, the mitigation amounts per percentage point of exceedance were determined for each power plant for a maximum potential mitigation of $1,500 per day when cooling water flow is at design levels (100%). This resulted in $75 per percentage point of exceedance at Pittsburg Power Plant and $300 per percentage point of exceedance at Contra Costa Power Plant.

c. Winter-Run Chinook Salmon Population Size
Compensation for exceeding prescribed operation limits would also consider the estimated winter-run chinook salmon run size as measured at Red Bluff diversion dam of the preceding year. The estimated run size provides a surrogate indication of overall winter-run chinook salmon abundance. If the estimated run size from the preceding year is low then the mitigation compensation would be greater since fewer eggs and subsequent juveniles are produced. A run size of 2000 was selected as a benchmark or threshold population level. Compensation is increased as the population level decreases below the 2000 fish benchmark.

In addition, a local abundance index representing the presence of juvenile winter-run chinook salmon near the power plants was considered but not implemented in the mitigation compensation program. Currently, there is very limited survey information on winter-run chinook salmon abundance in the Delta. Therefore, an index of local abundance near the power plants was not available. However, if surveys targeting winter-run chinook salmon in the future are initiated, they will be evaluated for inclusion into the winter-run chinook salmon mitigation compensation program.

ESTIMATING COMPENSATION

Compensation for exceeding circulating water thresholds above predetermined threshold volumes is assessed based on three basic parameters:

a. The extent of operation above the prescribed limits as measured by the number of percentage points the 7-day running average is above the prescribed 80 and 95% circulating water thresholds.

b. The amount of compensation per percentage point of exceedance of the respective 80 and 95% thresholds, $75 for Pittsburg and $300 for Contra Costa per percentage point of exceedance.

c. The estimated winter-run chinook salmon run size at Red Bluff diversion dam from the preceding year.

Compensation is assessed as follows:

a. A base level of mitigation is calculated based upon exceeding the cooling water flow threshold (80% of design flow at Pittsburg and 95% of design flow at Contra Costa). The base level mitigation also represents the theoretical maximum mitigation which is adjusted later to incorporate biological information. When the average flow has exceeded the threshold level, the percentage points of exceedance is calculated by subtracting the threshold percentage from the actual 7-day average flow percentage of design.

   Percentage points of exceedance = (7-day average flow/design flow) - 80% (Pittsburg),
   Percentage points of exceedance = (7-day average flow/design flow) - 95% (Contra Costa).

b. The base mitigation amount is the number of percentage points of exceedance the daily 7-day average is above threshold multiplied by $75 for Pittsburg or $300 for Contra Costa (Table F-2). Hence, only when the thresholds have been exceeded, is the daily base level of mitigation calculated as follows.

Base mitigation = percentage points of exceedance * $75 per percentage point (Pittsburg),
Base mitigation = percentage points of exceedance * $300 per percentage point (Contra Costa).

c. A mitigation adjustment is calculated at the end of the year based upon the winter-run adult escapement from the previous year (Table F-6). The adjustment serves to incorporate the potential abundance of juvenile winter-run chinook salmon into the calculation of the mitigation amount. The adjustment is multiplied with the base mitigation to determine actual mitigation at the end of the year,

actual mitigation = base mitigation * mitigation adjustment.

The annual winter-run chinook salmon run size as measured at Red Bluff diversion dam from the preceding year is used to determine the mitigation adjustment. When the run size is less than 2000 fish, then the population is considered to be at risk and the mitigation adjustment increases as the estimated run size falls (Table F-6),

However, when the run size is greater than 2000, then the population is considered to be not at high risk and the mitigation adjustment is 0 (Table F-6). For example, if the winter-run chinook salmon run size for 1991 was 1350 fish, then the mitigation adjustment for 1992 would be 0.35 and the base mitigation for February and March of 1992 would be multiplied by 0.35.

Table F-6. Mitigation Adjustment Factor Based Upon Adult Winter-Run Escapement at Red Bluff Diversion Dam [1]

Winter Run Escapement	Mitigation Adjustment
≥ 2000	0
1900 - 1999	0.05
1800 - 1899	0.1
1700 - 1799	0.15
1600 - 1699	0.2
1500 - 1599	0.25
1400 - 1499	0.3
1300 - 1399	0.35
1200 - 1299	0.4
1100 - 1199	0.45
1000 - 1099	0.5
900 - 999	0.55
800 - 899	0.6
700 - 799	0.65
600 - 699	0.7
500 - 599	0.75
400 - 499	0.8
300 -399	0.85
200 - 299	0.9
100 - 199	0.95
0 - 99	1

[1] If the run size is greater than or equal to 2000 fish then the population is not at dangerously low levels and the mitigation adjustment is zero, resulting in no mitigation penalty. However, as the run size decreases below 2000 fish the mitigation adjustment increases.

Example - Based on Contra Costa Power Plant, March of 1991 simulated VSD operational information and actual fisheries monitoring data:

a. March accumulated approximately 38 percentage points above threshold limits.

b. From Table F-2 and the formula for Contra Costa shown below, the base mitigation would be $11,400.

c. The estimated winter-run chinook salmon run size from 1990 was 441 fish (less than 2000), therefore, the mitigation adjustment would be 0.8 (Table F-6). Resulting in a mitigation at the end of the year of approximately $9,120 for March 1991 (formula above).

The resulting equations would be:

Base mitigation = percentage points of exceedance * $300 per percentage point = 38 * $300 = $11,400
Mitigation adjustment = 0.8
Actual mitigation = base mitigation * mitigation adjustment = $11,400 * 0.8 = $9,120

From the 1990 to 1997 simulation period, the mitigation adjustment varied from 0.45 to 0.95.

SIMULATION OF COMPENSATION METHOD

Simulation of Power Plant Circulating Flows under VSD Operation and Exceedance Levels

Figures F-1 and F-2 depict the 7-day running average of simulated circulating water flow under VSD operation for each plant. If the 7-day running average flow for the Pittsburg Power Plant goes above the 80% of design flow threshold level then the plant accumulates percentage points of exceedance. The exceedance is the percentage points above the threshold level. For example, if the 7-day average flows for a week are 82%, 84%, 85%, 86%, 88%, 85%, and 79% of design flow, then the plant accumulates 2 + 4 + 5 + 6 + 8 + 5, or 30 percentage points of exceedance for that week. The daily percentage points of exceedance were summed together for each month and are presented in the bar graph at the top of Figures F-1, F-2, F-10, and F-11.

Winter-Run Chinook Salmon Run Size

Figure F-9 is a graph of the winter-run chinook salmon run size as estimated at Red Bluff diversion dam from 1976 to 1996.

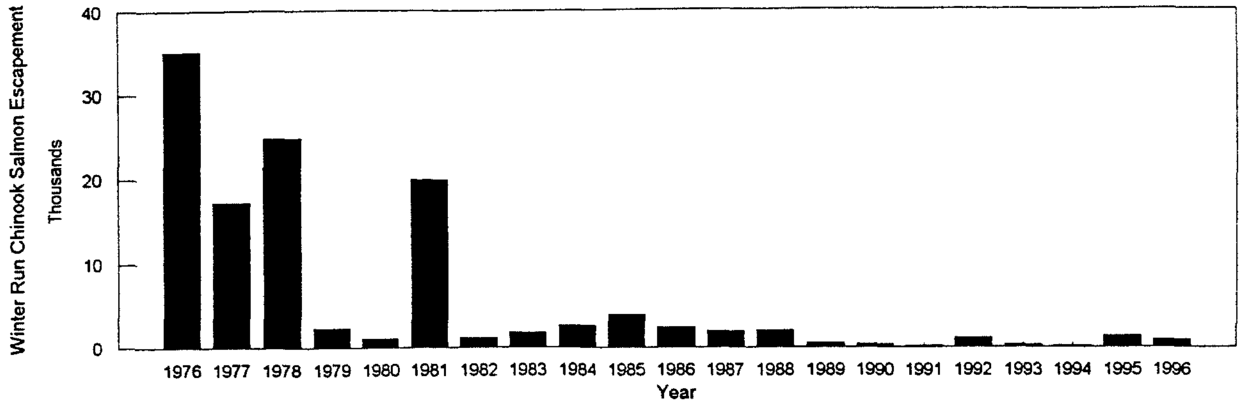

Figure F-9. Annual Winter-Run Chinook Salmon Spawning Escapements Counts at Red Bluff Diversion Dam (1976 - 1996).

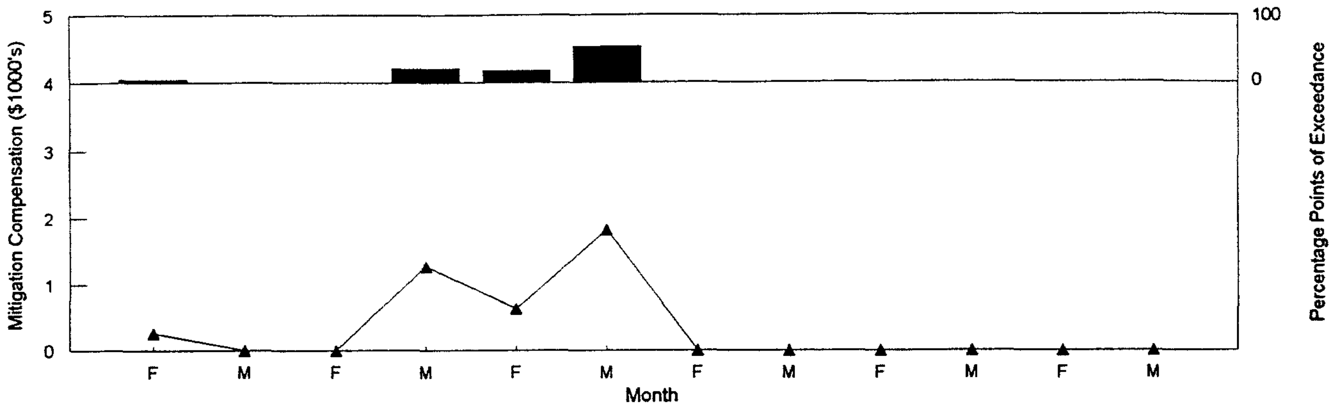

Figure F-10. Monthly Simulation of Compensation at the Pittsburg Powerplant for February through March for 1990, 1991, 1993, 1994, 1995, and 1997.

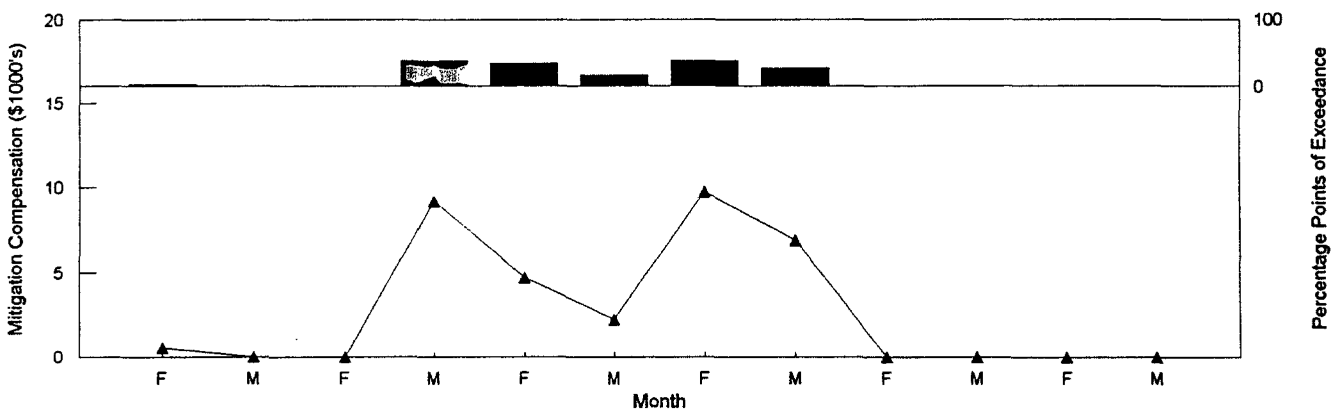

Figure F-11. Monthly Simulation of Compensation at the Contra Costa Powerplant for February through March for 1990, 1991, 1993, 1994, 1995, and 1997.

Simulation of Compensation

Figures F-10 and F-11 depict the method of estimating compensation for each plant for 1990, 1991, 1993, 1994, 1995, and 1997. The monthly exceedance-days were calculated based on the parameters discussed above and used in the formulas described above.

Potential Worst Case Annual Mitigation Based on Historical Data

The examples presented here use data provided by the agencies and PG&E during 1990, 1991, 1993, 1994, 1995, and 1997. These years were chosen to reflect a range of circulating water flows and varying water year types (i.e., normal, wet, and dry). These are the same years used in the VSD analysis presented in Appendix E.

The worst conditions for each month were extracted from the data sets to simulate the worst case annual mitigation amount. To clarify, the highest actual percentage points of exceedance in the dataset under VSD operation and the lowest annual winter-run chinook salmon run size were selected, independent of each other, such that they may or may not come from the same month or from the same year. The lowest winter-run chinook salmon run size to occur with our study years was 189.

Table F-7 illustrates the potential actual mitigation for the Pittsburg Power Plant based upon the lowest winter-run run size and the maximum cumulative percentage points of exceedance for a month. These numbers are not for any one particular year.

Table F-7. Potential Worst Case Mitigation Amount for Pittsburg Power Plant

MONTH	Winter-Run Run Size	Percentage Points	Base Mitigation Level	Mitigation Adjustment	Actual Mitigation
February	189	18.7	$1,403	0.95	$1,332.38
March	189	54.3	$4,073	0.95	$3,868.88
				Total	**$5,201.25**

Table F-8 illustrates the potential actual mitigation for the Contra Costa Power Plant based upon the lowest winter-run run size and the maximum cumulative percentage points of exceedance for a month. These numbers are not for any one particular year.

Table F-8. Potential Worst Case Mitigation Amount for Contra Costa Power Plant

MONTH	Winter-Run Run Size	Percentage Points	Base Mitigation Level	Mitigation Adjustment	Actual Mitigation
February	191	38.3	$11,490	0.95	$10,915.50
March	191	38.4	$11,520	0.95	$10,944.00
				Total	**$21,859.50**

Combined Potential Worst Case Annual Mitigation Based on Historical Data

The combined annual mitigation is determined by summing the annual mitigation amount for Delta smelt and the annual mitigation amount for winter-run chinook salmon for both power plants. From Table F-4 and F-5, the potential worst case annual mitigation amount incurred for Delta smelt at the Pittsburg and Contra Costa power plants would be $774 + $2,548, respectively, or $3,322. From Table F-7 and F-8, the potential worst case annual mitigation amount incurred for winter-run chinook salmon at the Pittsburg and Contra Costa power plants would be $5,201 + $21,860, respectively, or $27,061. Therefore, the combined annual mitigation amount for both power plants would be $30,383.

APPENDIX G. IMPLEMENTING AGREEMENTS BY AND BETWEEN PACIFIC GAS AND ELECTRIC COMPANY AND U.S. FISH AND WILDLIFE SERVICE AND NATIONAL MARINE FISHERIES SERVICE

(Reserved)